# High End Computer Network Testbedding at NASA Goddard Space Flight Center



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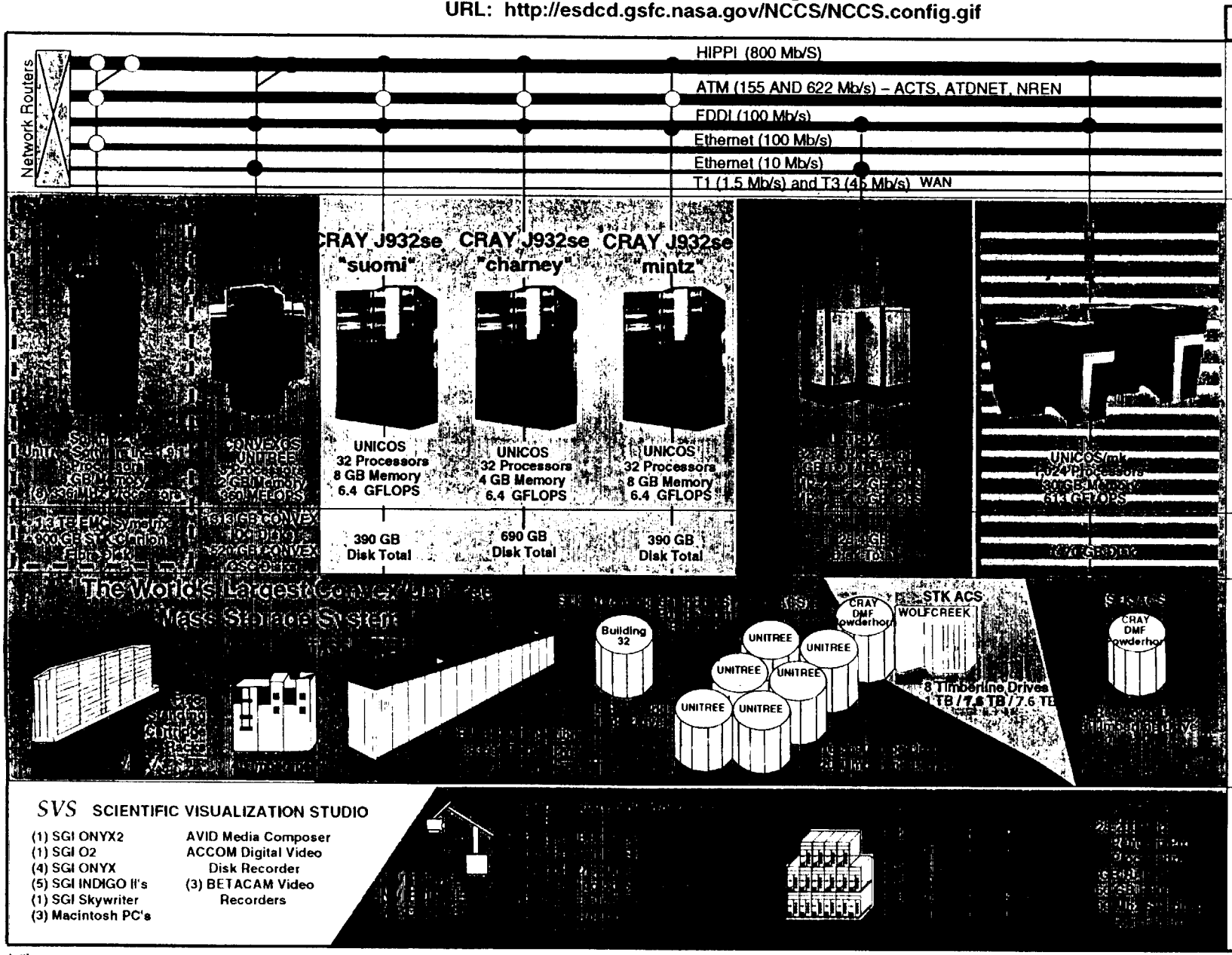
7th International Conference on Computer Communications and Networks

Earth & Space Data Computing Division

# Hardware Configuration

URL: http://esdcd.gsfc.nasa.gov/NCCS/NCCS.config.gif

October 1, 1998




J.Laue

NASA Center for Computational Sciences (NCCS)
NCCS CONVEX/UNITREE Mass Storage System
High Performance Computing and Communications (HPCC)

○ Not yet production
– – – To Be Installed

+ Includes backup capacity for user data

NA Not Applicable


# Ranking of the ESS Cray T3E Testbed

## *located at the NASA/Goddard Space Flight Center*

## Among Other Large Systems

***November 15, 1997***

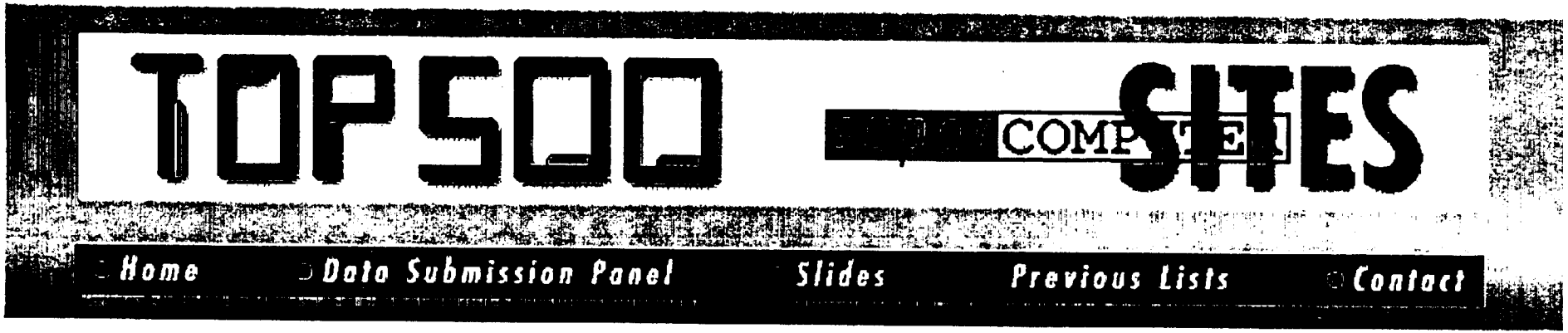
### TOP500 list of the World's most powerful computers

*http://www.netlib.org/benchmark/top500.html*

***The recently upgraded 896 processor T3E ranks:***
- *#5 in the world*

***Just the 512 processor ESS portion ranks:***
- *#1 in NASA*
- *#1 in the US among systems available to the NASA Science Community*
- *#9 in the world*

| Rank | Installation Site | Computer | GigaFLOPS based on the Linpack benchmark |
|---|---|---|---|
| 1 | Sandia National Labs, US | Intel ASCI Red-3632 | 1338 |
| 2 | National Security Agency, US | CRAY T3E-900 LC1248 | 634 |
| 3 | Meteorological Office, UK | CRAY T3E-900 LC840 | 430 |
| 4 | Uni of Tsukuba, Japan | Tsukuba CP-PACS/2048 | 368 |
| 5 | NERSC/LBNL, US | CRAY T3E-900 LC512 | 264 |
| 6 | Uni of Tokyo, Japan | Hitachi SR2201/1024 | 232 |
| 7 | National Aerospace Lab, Japan | Numerical Wind Tunnel | 229 |
| 8 | ECMWF, UK | Fujitsu VPP700/116 | 213 |
| 9 | Max-Planck-Gesellschaft, Germany | CRAY T3E LC672 | 196 |
| 9 | Cray Research, US | CRAY T3E LC544 | 196 |
| 9 | Forschungszentrum Juelich, Germany | CRAY T3E LC512 | 196 |
| **9** | **NASA GSFC, US** | **CRAY T3E LC512** | **196** |
| 9 | Pittsburgh SC, US | CRAY T3E LC512 | 196 |
| 9 | Universitaet Stuttgart, Germany | CRAY T3E LC512 | 196 |
| 10 | DOD/CEWES, US | CRAY T3E-900 LC312 | 166 |
| ... | ... | | |
| 500 | ... | | |




# TOP500

## (June 18, 1998)

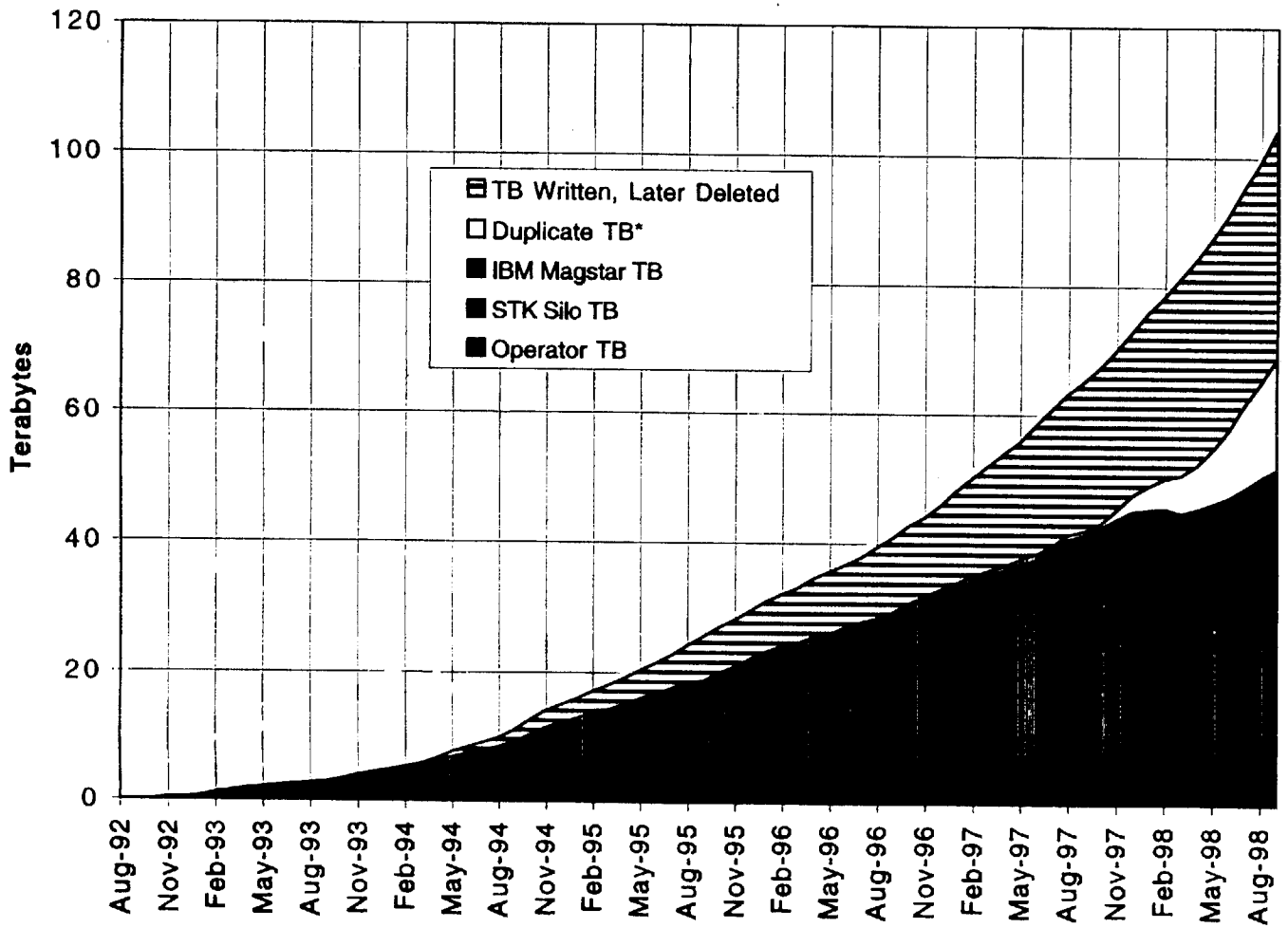
We try to implement links to the WWW-Homepages of all the sites listed in the table. Please send address of Homepages to top500@rz.uni-mannheim.de.

A table of 500 entries (ca. 120 KB) is loaded now ...

| Rank | Manufacturer | Computer | Rmax | Installation Site | Country | Year | Area of Installation | # Proc | Rpeak | Nmax | N1/2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Intel | ASCI Red | **1338000** | Sandia National Labs Albuquerque | USA | 1997 | Research | 9152 | 1830400 | 235000 | 63000 |
| 2 | SGI | T3E1200 LC1080-512 | **891500** | Government | USA | 1998 | Classified | 1080 | 1296000 | 259200 | 26400 |
| 3 | SGI | T3E900 LC1248-128 | **634200** | Government | USA | 1997 | Classified | 1248 | 1123200 | . | . |
| 4 | SGI | T3E900 LC840-128 | **450500** | United Kingdom Meteorological Office Bracknell | UK | 1997 | Research Weather | 840 | 756000 | . | . |
| 5 | SGI | T3E LC1024-128 | **448600** | NASA/Goddard Space Flight Center Greenbelt | USA | 1998 | Research Weather | 1024 | 614400 | 119808 | 19008 |

# NASA Center for Computational Sciences
# Mass Data Storage and Delivery System Cumulative Total Data Stored

2,857,778 active files, average size 18.99 MB




**October 1, 1998**

Unique Data: 51.7 TB
*Duplicated (Risk Mitigation) Data: 17.1 TB
Total *Active* Data: 68.9 TB

Aggregate Data Deleted: 35.4 TB
Cumulative Data Stored: 104.3 TB

ems 10/2/1998

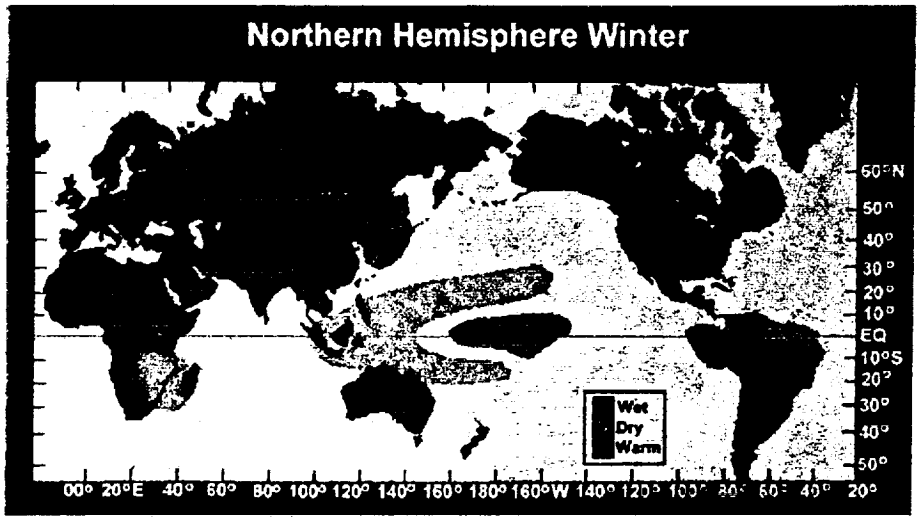
384 processors were added to the T3E last week to provide operational support to...

# NASA Seasonal to Interannual Prediction Project (NSIPP)

## Use Satellite Data to Understand and Predict El Nino...


http://nsipp.gsfc.nasa.gov/enso/sat/sststillanom.htm

## And its world wide effects...




http://nsipp.gsfc.nasa.gov/primer/englishprimer7.html

## Through Computer Simulation of the Climate System

# HPCC/Earth and Space Sciences (ESS) Project

*Goal: Demonstrate the potential afforded by balanced Teraflop/s systems performance to further our understanding and ability to predict the dynamic interaction of physical, chemical, and biological processes affecting the Earth, the solar-terrestrial environment, and the universe.*

http://sdcd.gsfc.nasa.gov/ESS/

## Round-2 ESS Grand Challenge Investigators

**$12.6M over 3 years**

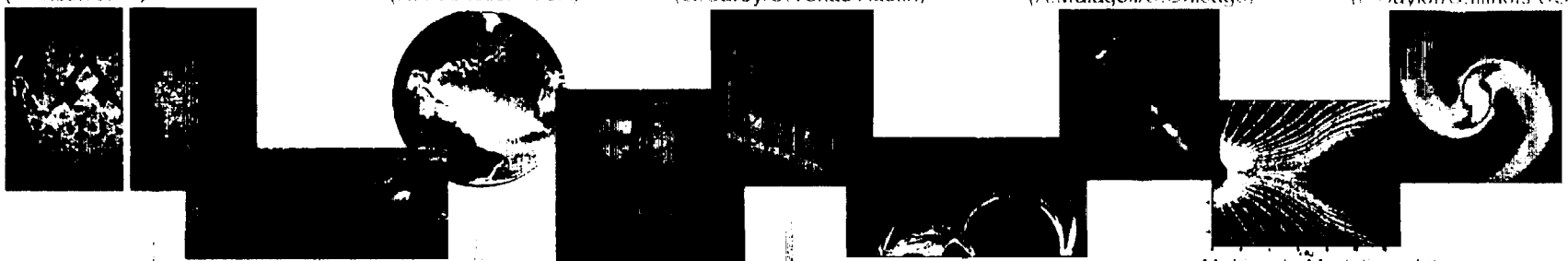
Simulations of the Earth's Core and Mantle Dynamics (P.Olson/JHU)

Atmosphere/Ocean Dynamics and Tracers Chemistry (R.Mechoso/UCLA)

Rayleigh-Benard-Marangoni Problems in a Microgravity Environment (G.Carey/U.Texas Austin)

Turbulent Convection and Dynamos in Stars (A.Malagoli/U.Chicago)

Relativistic Astrophysics and Gravitational Wave Astronomy (P.Saylor/U.Illinois UC)



SAR Interferometry and Imaging Science (D.Curkendall/JPL)

Four Dimensional Data Assimilation (P.Lyster/U.Maryland)

Solar Activity and Heliospheric Dynamics (J.Gardner/NRL)

Multiscale Modeling of the Heliosphere (T.Gombosi/U.Michigan)

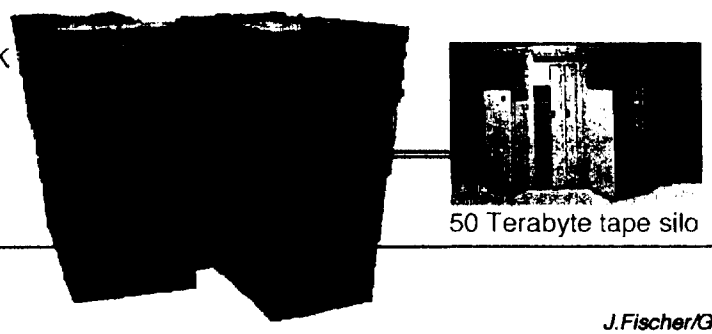
| **Performance Milestone Achievements** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 100 Gigaflop/s | | | | | | | | | |
| 50 Gigaflop/s | ✔NHSE | ✔ | | | ✔ | ✔NHSE | ✔ | ✔ | ✔ |
| 10 Gigaflop/s | ✔NHSE | ✔ | ✔NHSE | ✔NHSE | ✔NHSE | ✔NHSE | ✔NHSE | ✔NHSE | ✔NHSE |

**Collaborations to restructure specified Investigator codes to achieve milestone performance**

"NHSE" indicates codes that have been made available to the scientific community via the National HPCC Software Exchange - http://www.nhse.org/

## 512 Processor SGI/Cray T3E at GSFC

176 Gflop/s on LINPACK
#1 in NASA
#9 in the world



50 Terabyte tape silo

**$13.2M over 3 years**

## 50 Gigaflop/s-Sustained Testbed

*J.Fischer/GSFC 980313*

# Science Investigation

- Grand Challenge (GC) Science: Turbulent Convection and Dynamos in Stars
- GC PI: Andrea Malagoli/U. of Chicago
- With Co-I's at:
  - » U. of Colorado at Boulder
  - » U. of Minnesota
  - » Argonne National Laboratory (ANL)
- URL: http://astro.uchicago.edu/Computing/HPCC/
- Sponsor: HPCC/ESS Project via Round 2 CAN

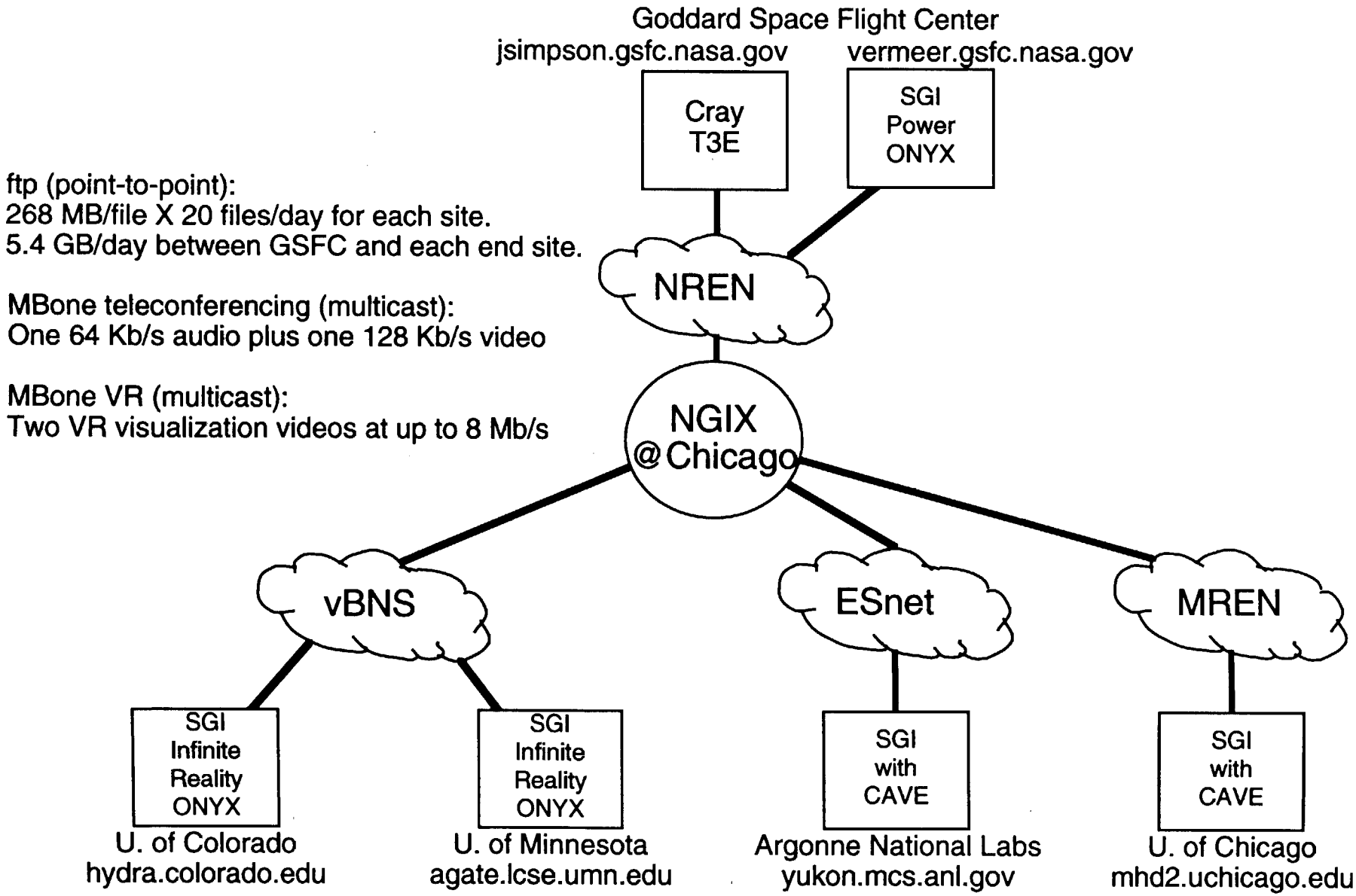
# New Collaborative Research

- Data sets generated by three different models on jsimpson Cray T3E at GSFC sent back to respective University creators (268 Mbytes/file X 20 files/day for each site)
- Universities multicast their data sets to the other sites
- Distributed VR visualizations using ImmersaDesk (GSFC, U's of Colorado & Minnesota) and CAVE (ANL) (2 VR video streams at up to 8 Mbps)
- Simultaneous video conferencing during the distributed visualizations (128 Kbps video plus 64 Kbps audio)
- Plan summary at lcd-www.colorado.edu/nren

# Multiple High Performance Network Interconnections

## Enabling Scientific Data Flows for

## HPCC ESS Grand Challenge Team Lead by PI A. Malagoli/U. of Chicago

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# Breakthrough Use of High Performance Networks

- New peering agreements with ATM 155 Mbps connections at the Next Generation Internet Exchange (NGIX) in Chicago among NASA/NREN, NSF/vBNS, DoE/ESnet, and U. of Chicago/MREN
- End-to-end data transfers at greater than 60 Mbps among sites individually connected to NREN (GSFC), vBNS (U's of Colorado and Minnesota), ESnet (ANL), and MREN (U. of Chicago)
- Real time reliable multicast delivery
- Timing delay constraints drive quality-of-service research

# Recent Achievements

- Established ATM-based virtual circuits through the NGIX@Chicago among each of the remote PI sites and GSFC
- Example throughput performance obtained from GSFC Cray T3E to U. of Colorado:
  - » 41.8 Mbps (avg) in 128 MByte transfers w/8 KByte buffers
  - » 45.8 Mbps in 1 GByte transfers w/8 KByte buffers
  - » 65.1 Mbps in 1 GByte transfers w/16 KByte buffers
  - » 65.2 Mbps in 1 GByte transfers w/32 KByte buffers
  - » 74.5 Mbps in 1 GByte transfers w/64 KByte buffers
- Started efforts to enable multicast transfers

# High End Computer Networking

## *Application Drivers for High End Computer Networking*

- Distributed supercomputing
- Virtual reality applications, e.g.,
  - » TerraVision 3D browser of remotely accessed data
  - » Cave Automatic Virtual Environments (CAVE)
- Workstations access/displaying data from multiple CAVE's
- Video servers to client workstations
- Group/project collaborations using a combination of video, data, voice, and shared whiteboarding
- Increased use of multi-media applications
- Backbone interconnections of gigabit per second LAN's

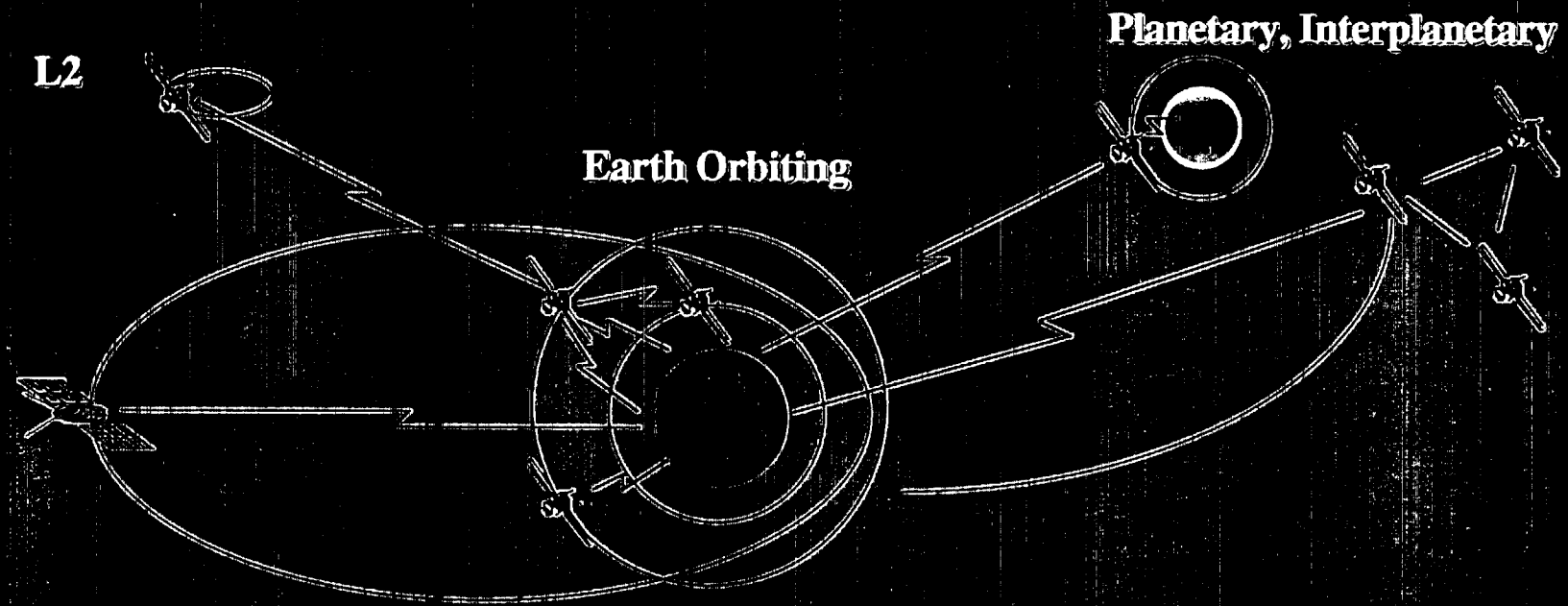
# Importance of Computer Networking

"The ability of a network to knit together the members of a sprawling community has proved to be the most powerful way of fostering scientific advancement yet discovered."

Peter Denning, "The Science of Computing, Computer Networks,"American Scientist, March-April 1985, p. 127.

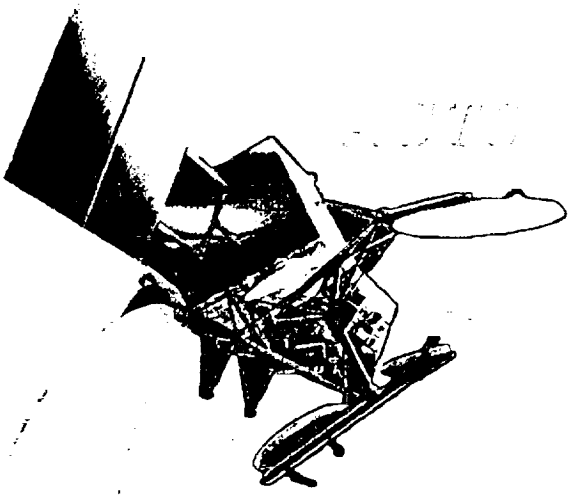
# SSAIP Vision:

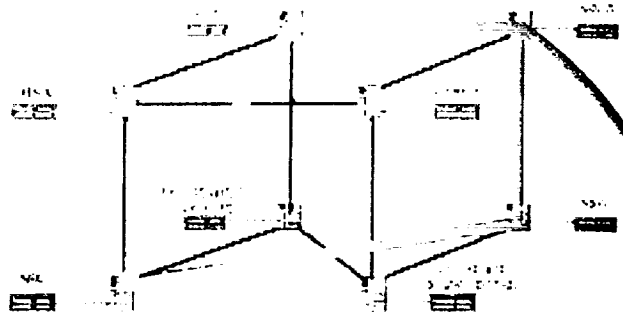
- Provide scientist with the required instrument data fused to any other required data to provide information products based on their particular need at any given time.
- Provide any investigator with the ability to be able to seamlessly access any instrument data for their needs or information set from any point on the Earth or in the Solar System.




Dennis J. Andrucyk
dennis.andrucyk@gsfc.nasa.gov

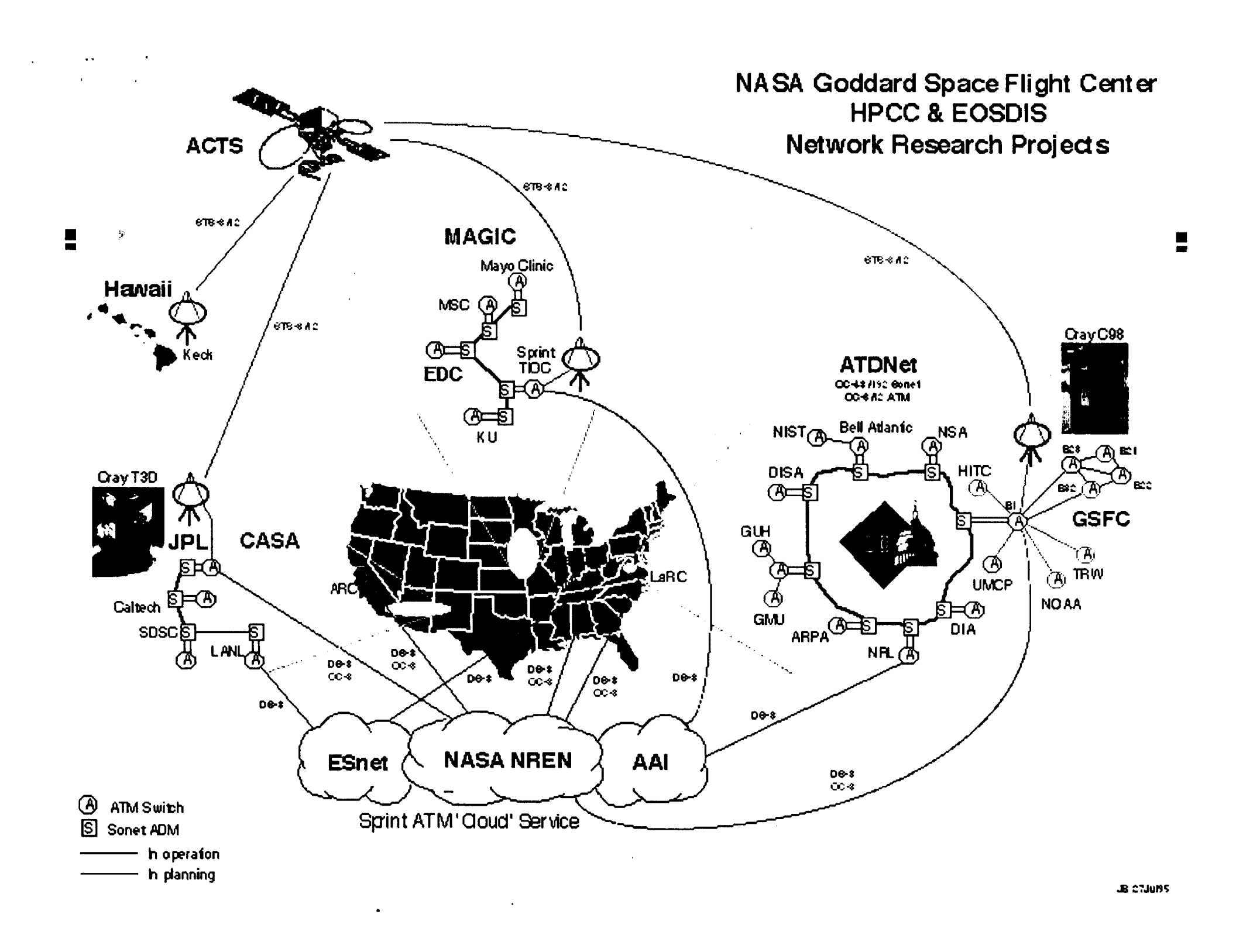
**Extend the Data Network to Include All Spaceborn Resources**

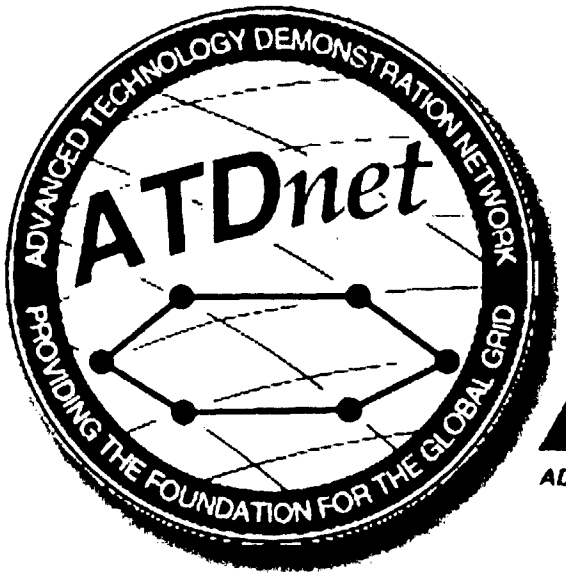




# HPCC/ESS High End Computer Networking

bf - 3/5/97

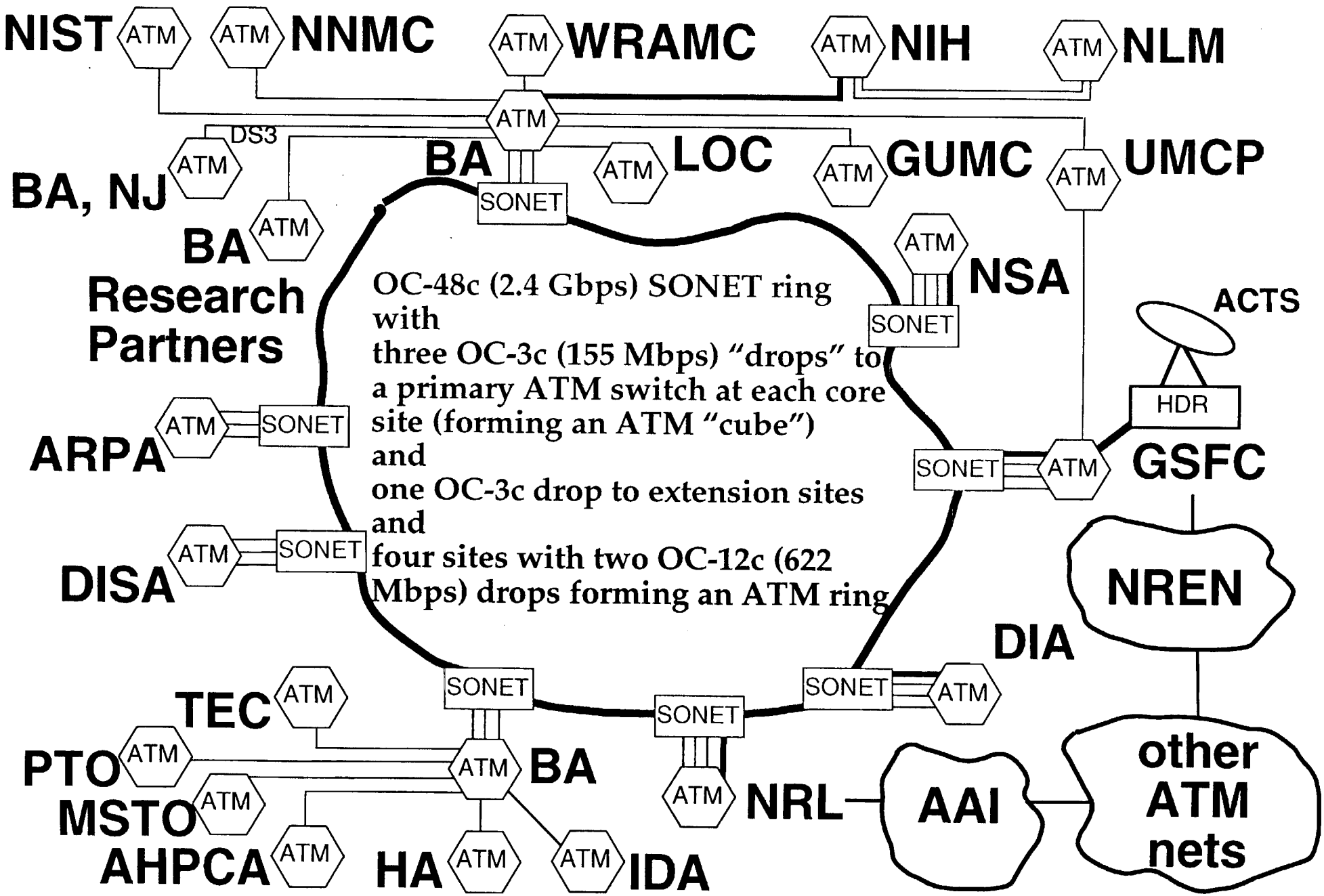

NASA Goddard Space Flight Center
HPCC & EOSDIS
Network Research Projects
ACTS
Hawaii
Keck
MAGIC
Mayo Clinic
MSC
EDC
Sprint
TIDC
KU
Cray C98
ATDNet
NIST
Bell Atlantic
NSA
DISA
HITC
GSFC
TRW
NOAA
UMCP
GLH
GMU
ARPA
NRL
DIA
Cray T3D
JPL
CASA
Caltech
SDSC
LANL
ARC
LaRC
ESnet
NASA NREN
AAI
Sprint ATM 'Cloud' Service
ATM Switch
Sonet ADM
h operation
h planning




# ATDnet

ADVANCED TECHNOLOGY DEMONSTRATION NETWORK

# ATDNet SONET/ATM Gigabit Network

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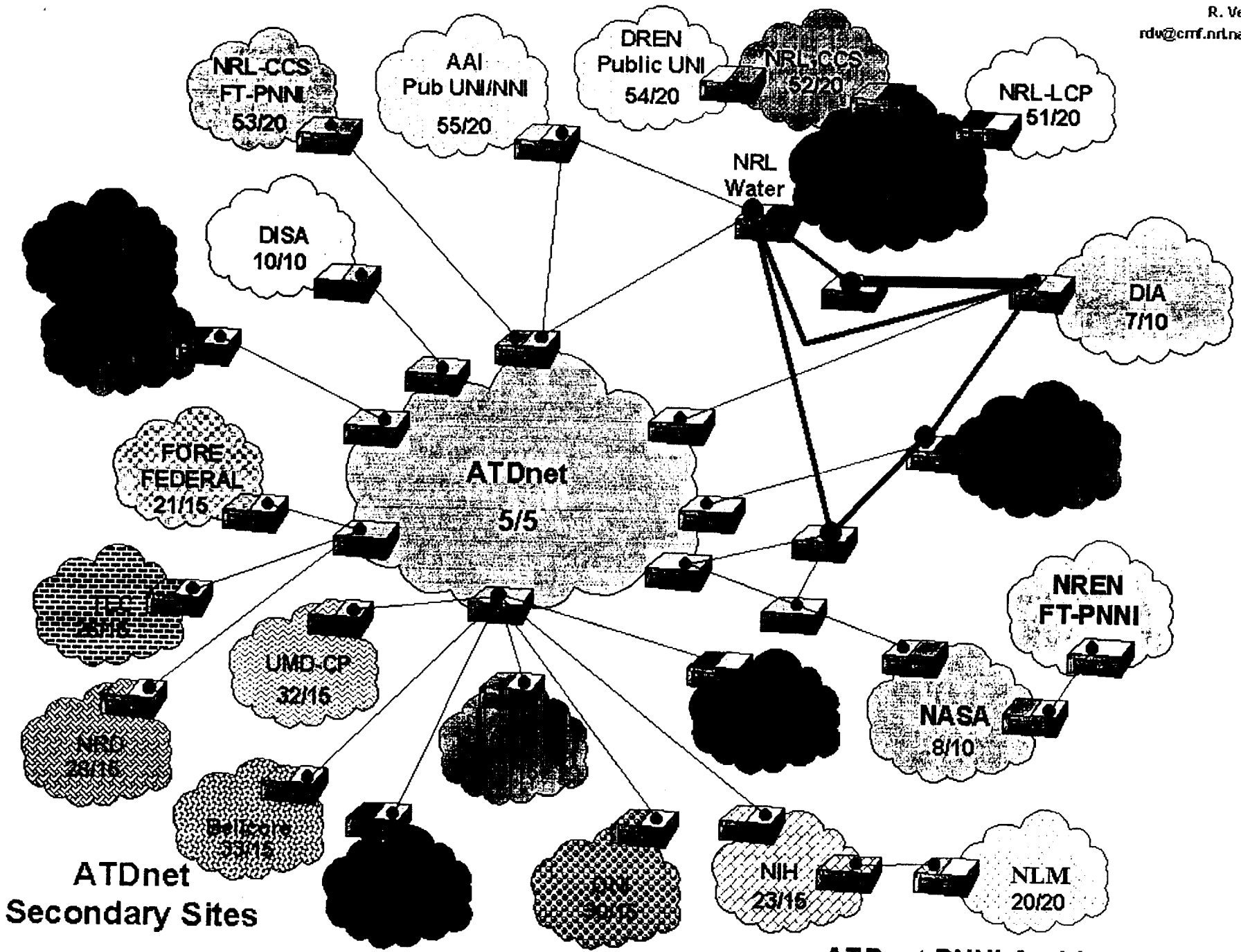
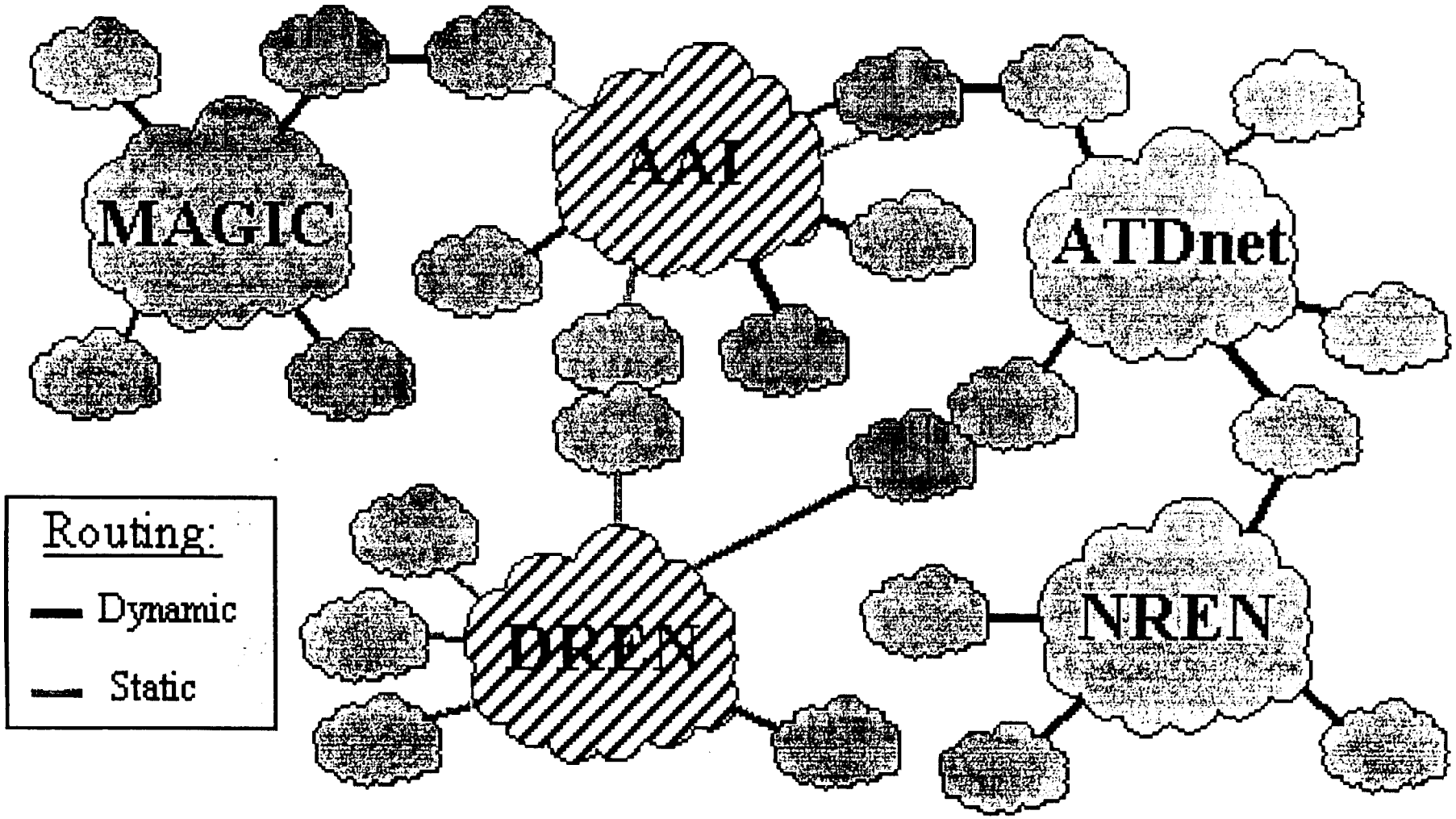
R. Verjinski
rdv@cmf.nrl.navy.mil



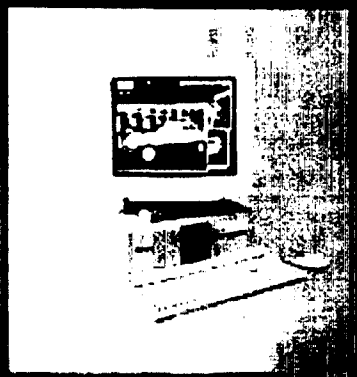

ATDnet PNNI Architecture, 9/6/98

# AAI/ATDnet/MAGIC/NREN/DREN "PNNI" Architecture



# GSFC <-> NRL OC-12 1 TB Challenge

shasta-a.nasa.atd.net



Sun UltraSPARC-2/300
Solaris 2.6 (128M)
SunATM-622 (2.1)

HPCC ATM

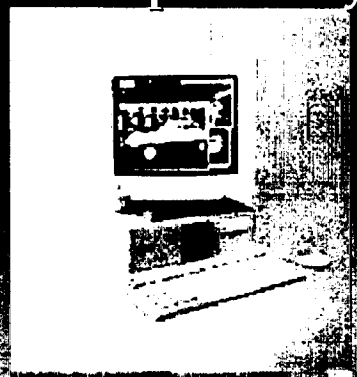
Using nttcp to transfer 1 TB of data
via Classical IP
(-l8192, -n134217728, -w512)

(5 h 52 m 26 s)
77% - 415.9686 Mbps - 85%

For comparison purposes, at T1 speed
it would take more than 66 days
to transfer 1 TB of data

ATDnet

fozzie-a.lcp.nrl.navy.mil



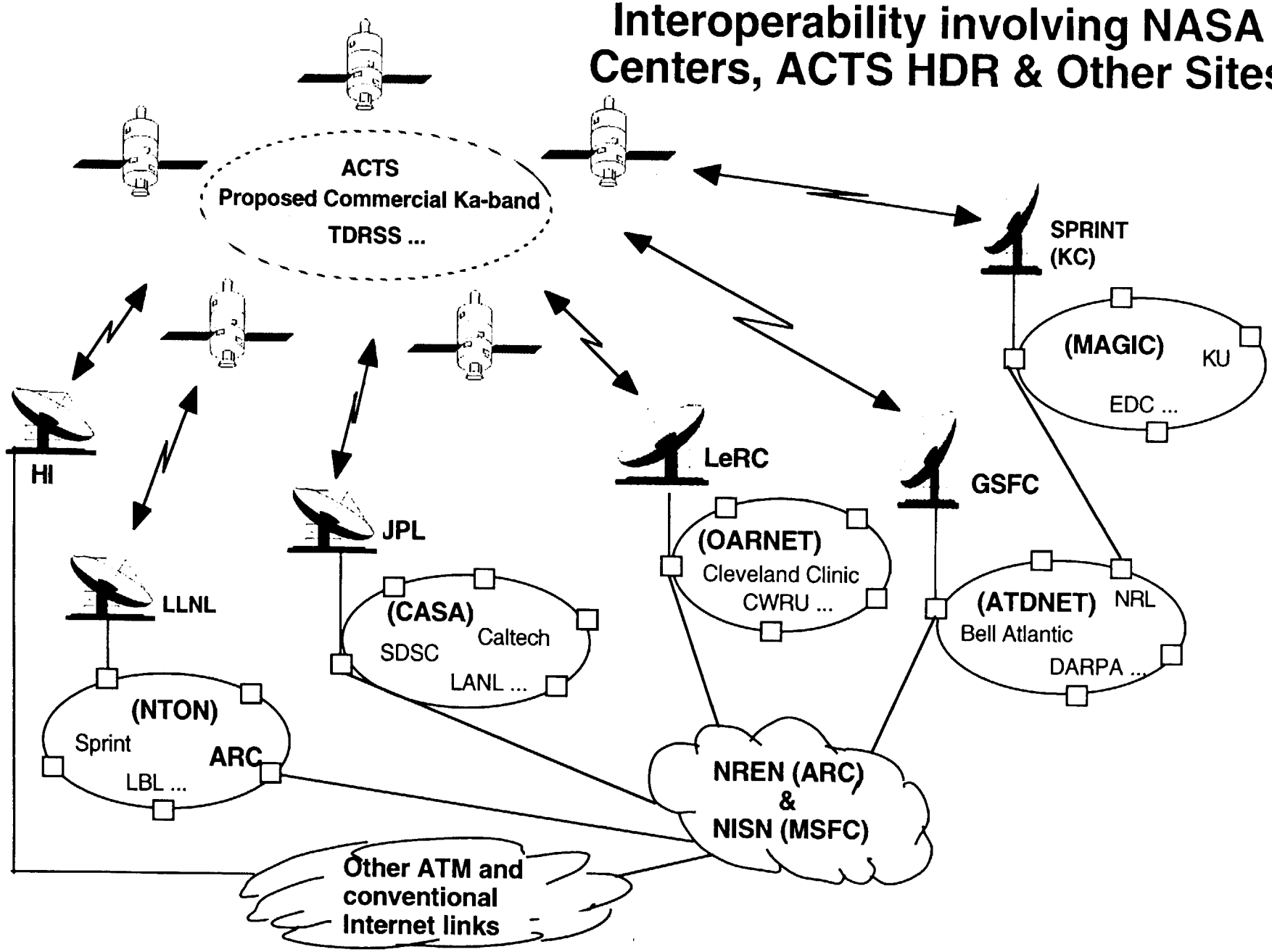
Sun UltraSPARC-2/300
Solaris 2.6 (128M)
SunATM-622 (2.1)

NRL ATM

OC-12c ATM
MTU = 9180

Round Trip Time (RTT) ~ 1.4 ms
Maximum OC-12c ATM TCP Performance ~ 540 Mbps
Bandwidth*Delay ~ 92 KB

# Testbed for Satellite and Terrestial Interoperability involving NASA Centers, ACTS HDR & Other Sites

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# Testbed for Satellite and Terrestrial Interoperability (TSTI)

## ***Objective***

Develop and demonstrate high degree of interoperability between satellite- and terrestrial-based networks

- Develop and evaluate enhancements to protocols such as ATM and TCP/IP
- Test and demonstrate new interface equipment hardware and software
- Utilize and showcase ACTS performance, especially its high data rate capabilities
- Extend HPCC network research program in Large Scale Networks
- Open to U.S. satellite and terrestrial communications carriers, equipment suppliers, and network providers

JPG 12/10/96

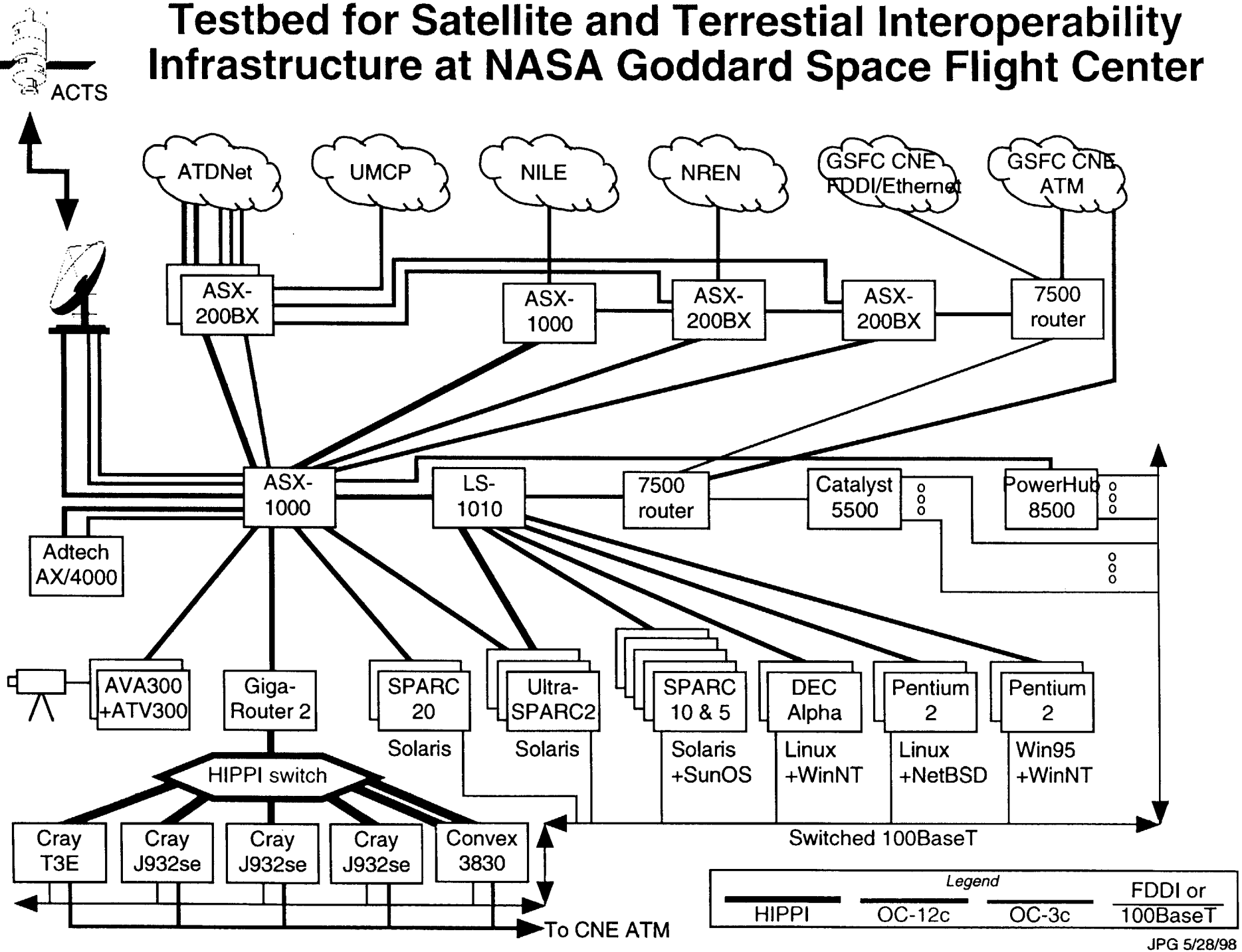
# Testbed for Satellite and Terrestrial Interoperability (TSTI)

## *Specific Technical Objectives*

Facilitate and conduct research and evaluations of new computer networking protocols and related technologies which improve the interoperability of satellite and terrestrial networks, e.g.,

- » TCP: large windows (RFC 1323), SACK (RFC 2018), XTP (RFC 1453)
- » IP: TAG (cisco), flow (Ipsilon), multi-protocol label switch (IETF), RSVP, multicasting, IPv6
- » ATM: MPOA, PNNI, available bit rate traffic management

# Testbed for Satellite and Terrestial Interoperability Infrastructure at NASA Goddard Space Flight Center

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# Collaborations/End Sites with GSFC/930 In TSTI-based Evaluations - Present

| Applications | Sat./Terr. Carriers | Academia | Federal |
|---|---|---|---|
| DGCM | ACTS Exp. #92 | UCLA | GSFC/910, JPL |
| Telemedicine | AAMnet/#118g | [SFU] | NLM |
| Teleradiology | AAMnet/#118f | [WashU] | NIH |
| TerraVision | AAMnet/#118e | | EDC, LeRC |
| Teleradiology | ATDNet-ACTS/#110 | UHI, GUMC | [TAMC] |
| GLIN | ATDNet, Comsat/Intelsat | UMD(Balti.County) | LOC |
| Trans-Pacific DL | ATDNet, Comsat/Intelsat, ACTS/NREN, MPT/CRL | | LOC, NLM, [Smithsonian,] National Library of Japan |

# Collaborations/End Sites with GSFC/930 In TSTI-based Evaluations - Present

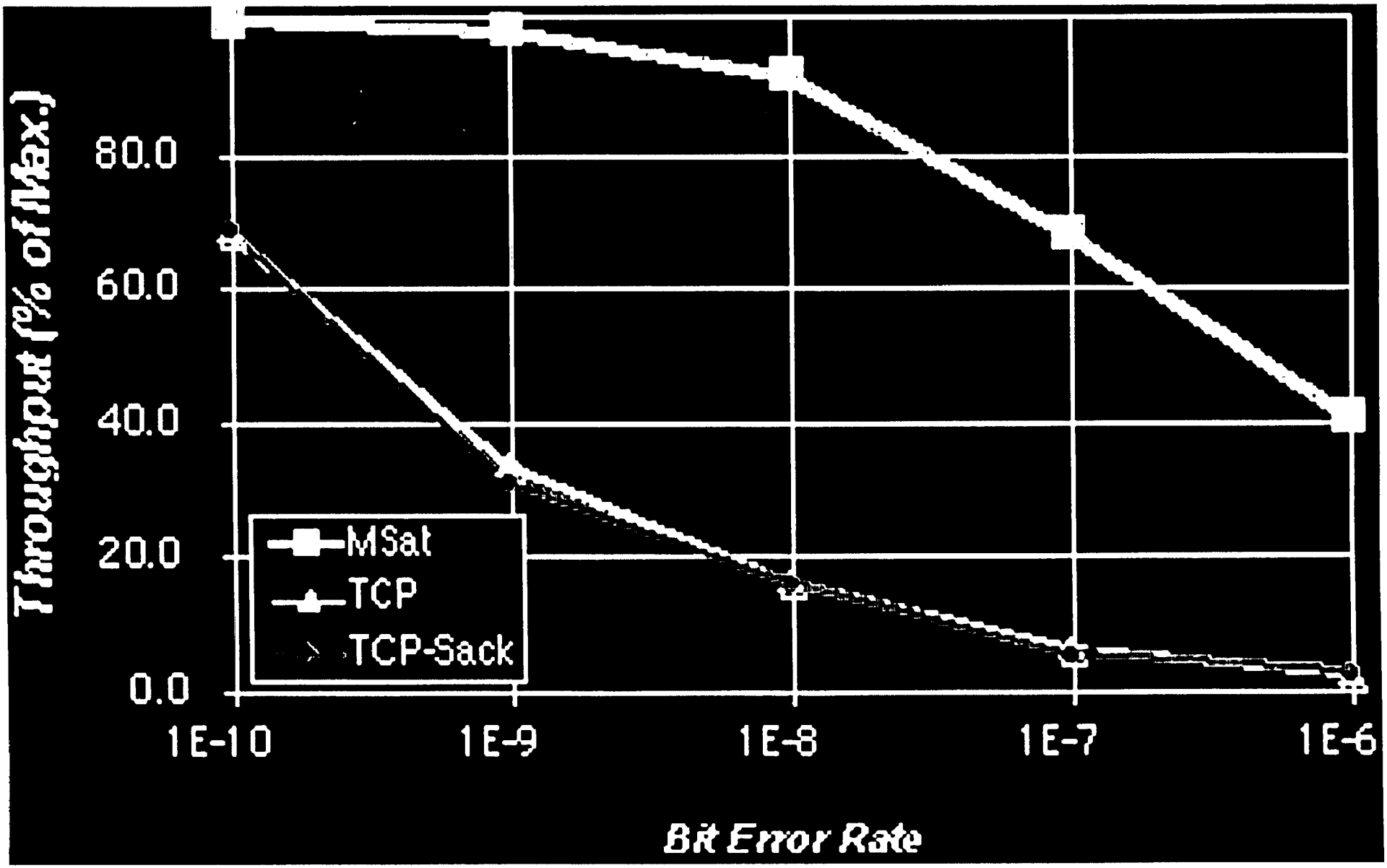
| Technology | Industry | Academia | Federal |
|---|---|---|---|
| TCP LFN (RFC 1323) | | KU | LeRC, JPL |
| TCP SACK (RFC 2018) | PSC | UCLA | GSFC/505 & 540 |
| XTP (RFC 1453) | Mentat | Concordia U. (Quebec) | Sandia N.L. |
| IP/TAG Switching (IETF MPLS WG) | Ipsilon, Cisco | | GSFC/505, ARC |
| IPv6/RSVP | | | GSFC/505 |
| ATM Transport Drivers | | UMD(College Park) | NSA |
| ATM OC-3c Firewall | STK/NSC, SPOCK | | NSA |
| ATM OC-12c Encryption | SECANT, SPOCK | | NSA |

# Testbed for Satellite and Terrestrial Interoperability (TSTI)

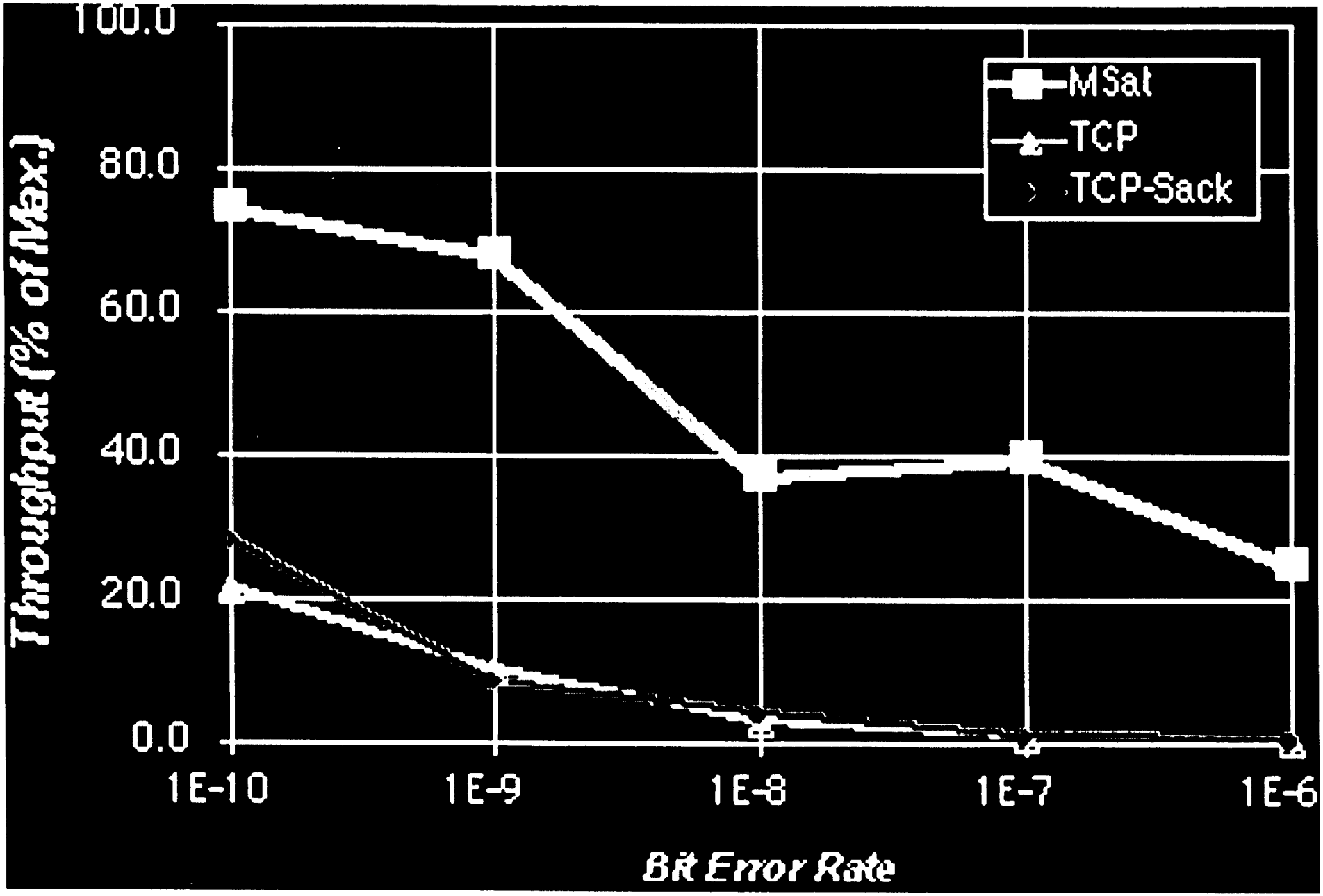
## A FY98 Program Product of 632-50-50 Communications - Terrestrial

- Recent Major Accomplishments
  - » Enabled first use of ACTS high data rate capabilities by GUMC, KU, NIH, and NLM
  - » Monthly highlights online at http://everest.gsfc.nasa.gov/month.html
  - » Charalambos, C., et al., "Experimental and Simulation Performance Results of TCP/IP over High-Speed ATM over ACTS", http://www.ittc.ukans.edu/~ccharala/research.html
  - » LeRC set ACTS highwater throughput performance
    - 520 Mbps memory-to-memory
    - 320 Mbps aggregate (3 streams) tape-to-tape
  - » Protocol performance baselining by GSFC
    - TCP, TCP-SACK, XTP
    - BER: 0, 10E-11, 10E-10, 10E-9, 10E-8, 10E-7, 10E-6, 10E-5
    - Delay: 0, 5, 71, 540 ms

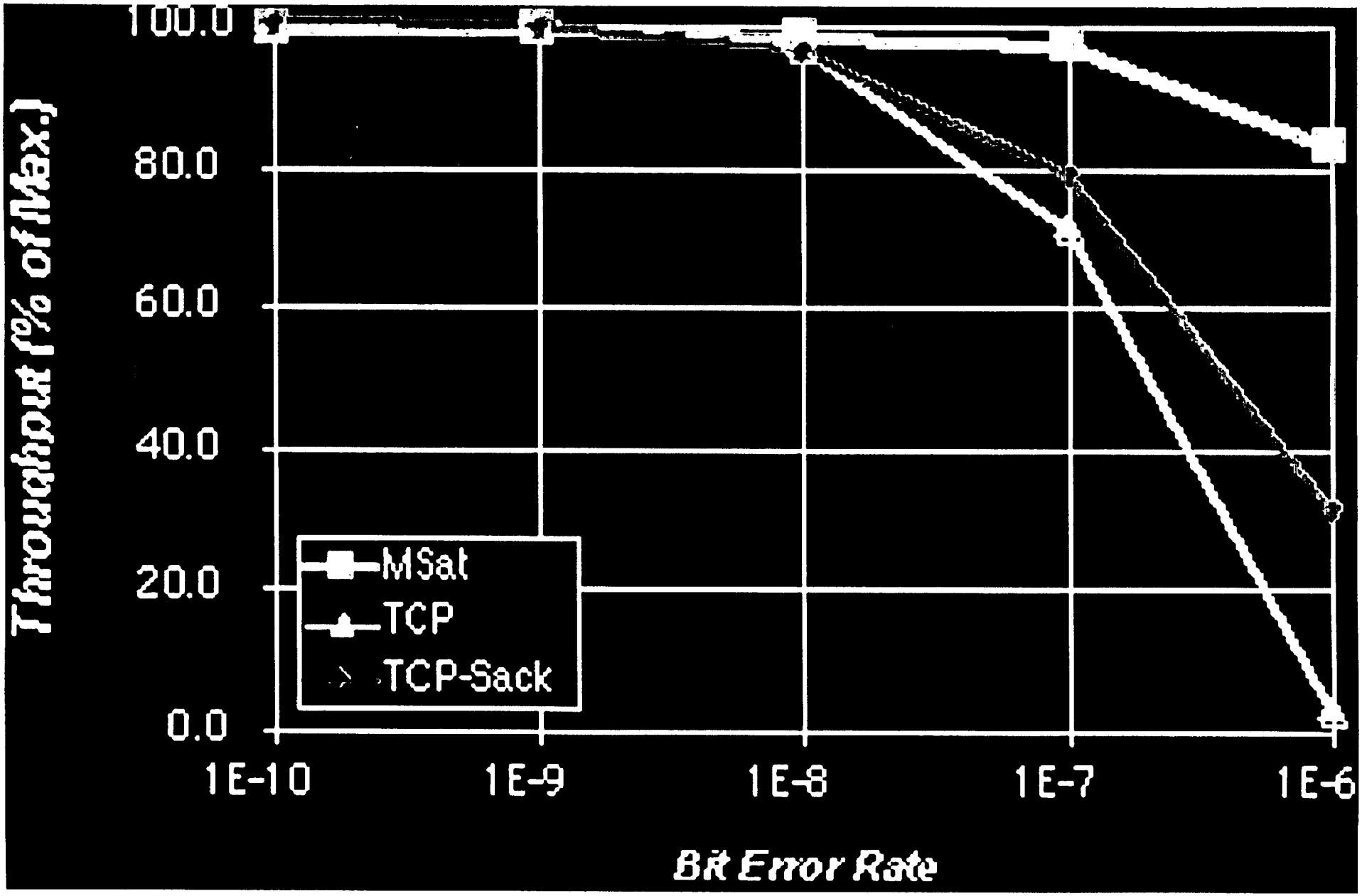
# WAN Conditions (RTT = 70 ms)



# Satellite Conditions (RTT = 540 ms)

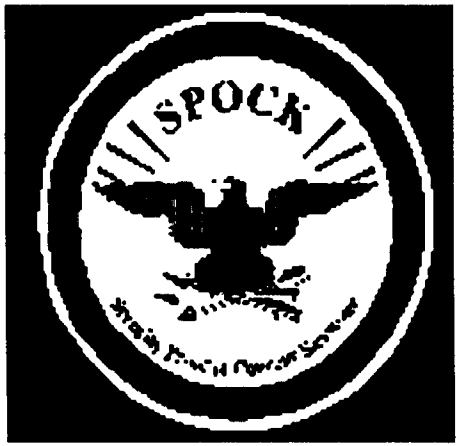


# LAN Conditions (RTT = 1 ms)



# SPOCK
# Security Proof of Concept Keystone

- NSA sponsored program
  - » SPOCK is a joint government-industry consortium sponsored by NSA to demonstrate security features of commercial and government products that can support dependable security architectures. This activity provides a forum for government users and security technology providers to share information on security requirements, emerging technologies, and new product developments. Integrators and product developers are afforded opportunities to share new solutions, identify government developed technology available for commercial use, and prototype COTS products in government sponsored test beds.
- NSA V2: Industry/Government Partnerships and Commercial Security Evaluations
  - » With NIST
- http://www.coact.com/spock.html




# Spock Program

## Security Proof of Concept Keystone

Spock Goals

Spock Activities

Spock Meetings

Spock Minutes

Spock Agenda

Home

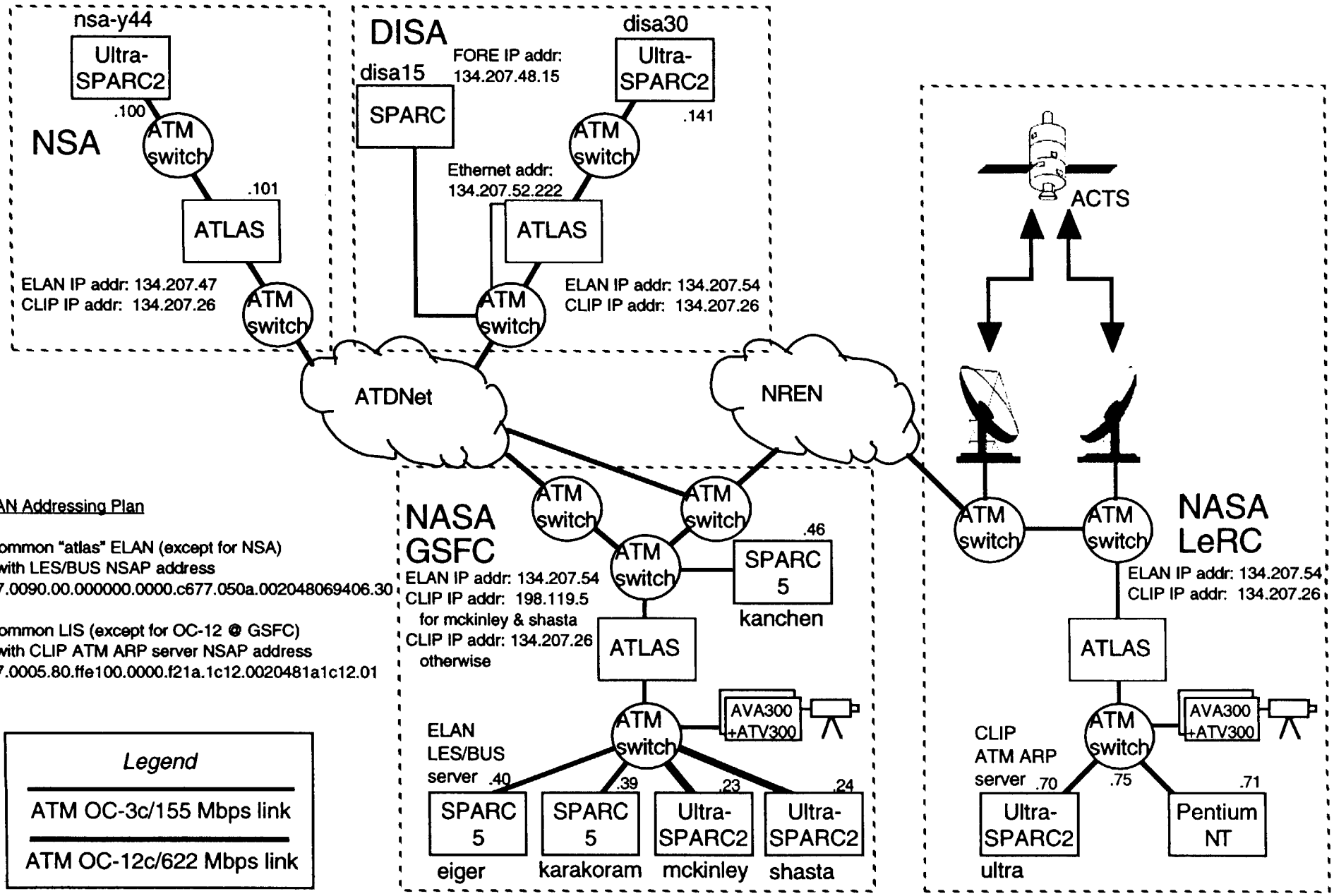
SPOCK is a joint government-industry consortium sponsored by NSA to demonstrate security features of commercial and government products that can support dependable security architectures. This activity provides a forum for government users and security technology providers to share information on security requirements, emerging technologies, and new product developments. Integrators and product developers are afforded opportunities to share new solutions, identify government developed technology available for commercial use, and prototype COTS products in government sponsored test beds.

The SPOCK FORUM meets monthly at COACT, Inc. For more information about the program or reports on Proof-of-Concept and test efforts contact: Terry Losonsky (NSA/V) @410-859-6318 or Jim McGehee (COACT, Inc.) @301-498-0150

# STK/NSG ATLAS Features of General Interest to NASA GSFC in the SPOCK Evaluations

- Securing ATM networks at full duplex OC-3c/155 Mbps speeds via selective filtering using a programmable policy cache architecture applied in firmware
- Extending IP security policy into an ATM environment by providing filtering of IP addresses by host, group, or network and by ICMP, TCP, or UDP protocols
- Providing an audit trail of unauthorized access attempts which in near time can be automatically sent to another host where it can be later viewed and archived
- Providing standards compliant encryption/decryption enabling strong data privacy

# Configuration for SPOCK Evaluation of STK/NSG ATLAS ATM Firewall




LAN Addressing Plan

Common "atlas" ELAN (except for NSA)
with LES/BUS NSAP address
47.0090.00.000000.0000.c677.050a.002048069406.30

Common LIS (except for OC-12 @ GSFC)
with CLIP ATM ARP server NSAP address
47.0005.80.ffe100.0000.f21a.1c12.0020481a1c12.01

*Legend*

ATM OC-3c/155 Mbps link

ATM OC-12c/622 Mbps link

JPG 8/21/98

## Performance Comparison Results Without and With STK/NSG ATLAS

- Used nttcp; all tests ran with window size=64, buflen=65536, nbuf=2048.

- Computers interconnected at 155 Mbps ATM over ATDNet:

| | | | |
|---|---|---|---|
| GSFC: | mckinley | Solaris 2.6 | Generic sun4u sparc SUNW,Ultra-2 |
| NSA: | nsa_y44 | Solaris 2.6 | Generic sun4u sparc SUNW,Ultra-2 |

- Host addresses:

| | | ELAN | CLIP |
|---|---|---|---|
| GSFC: | mckinley | 134.207.54.23 | 198.119.05.23 |
| NSA: | nsa_y44 | 134.207.47.100 | 134.207.26.100 |

- Performance Comparison Results (Mbps) from 13-Aug-1998:

| | Via CLIP | | Via ELAN | |
|---|---|---|---|---|
| | TO GSFC | FROM GSFC | TO GSFC | FROM GSFC |
| **Without ATLAS** | | | | |
| NSA: | 106.6355 | 79.8240 | 104.6224 | 79.1846 |
| **With ATLAS In Line Without Encryption** | | | | |
| NSA: | 101.7831 | 76.1600 | 100.5655 | 76.0065 |
| **With ATLAS In Line With Encryption** | | | | |
| NSA: | 100.3329 | 76.1567 | 99.8383 | 75.5812 |

# G7 Information Society Projects

# Trans-Pacific Digital Library Experiment

## *Objectives*

- Demonstrate and evaluate use of high performance satellite communications and advanced data communications protocols to enable interactive digital library data access between the U.S. Library of Congress, the National Library of Japan, and other digital library sites at 155 Mbps
  - » The satellite links demonstrate effective use of geostationary satellite-based communications in the Global Information Infrastructure
  - » The data communications protocols will include both standard protocols with recently specified options for performance enhancements and experimental protocols designed for improved performance
  - » Access will include interactive searches and retrievals of new on-line digital library data, and will promote an understanding of the need for ready access to these data

# Trans-Pacific Digital Library Experiment

## *U.S.-led Applications*

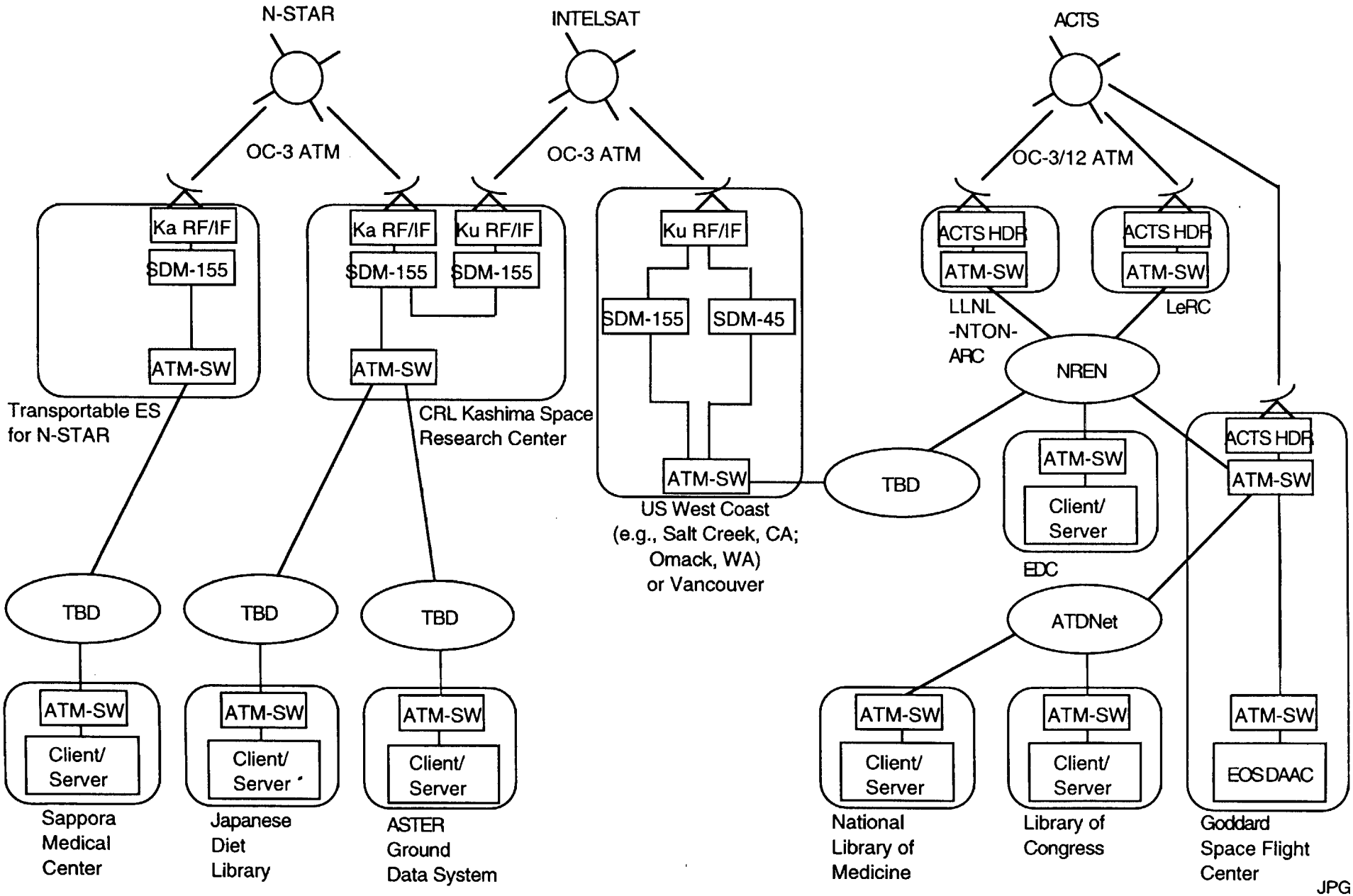
- Law Library of the Library of Congress
  - » Global Legal Information Network
- NASA Goddard Space Flight Center
  - » Trans-Pacific Access to GLOBE Visualizations in Real Time
- NIH National Library of Medicine
  - » Multi-Lingual Digital Anatomical Data Base
- USDA National Agricultural Laboratory
  - » Plant Genome Databases

# Trans-Pacific Digital Library Experiment

## ***Network Planners***

- NASA's Goddard Space Flight Center (GSFC), Lewis Research Center (LeRC), and Jet Propulsion Laboratory (JPL)
- Intelsat/Comsat
- Japan MPT's Communications Research Laboratory (CRL)
- George Washington University

# Configuration of Networks for Trans-Pacific Digital Library Experiment

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05/19/98

# Trans-Pacific Digital Library Experiment

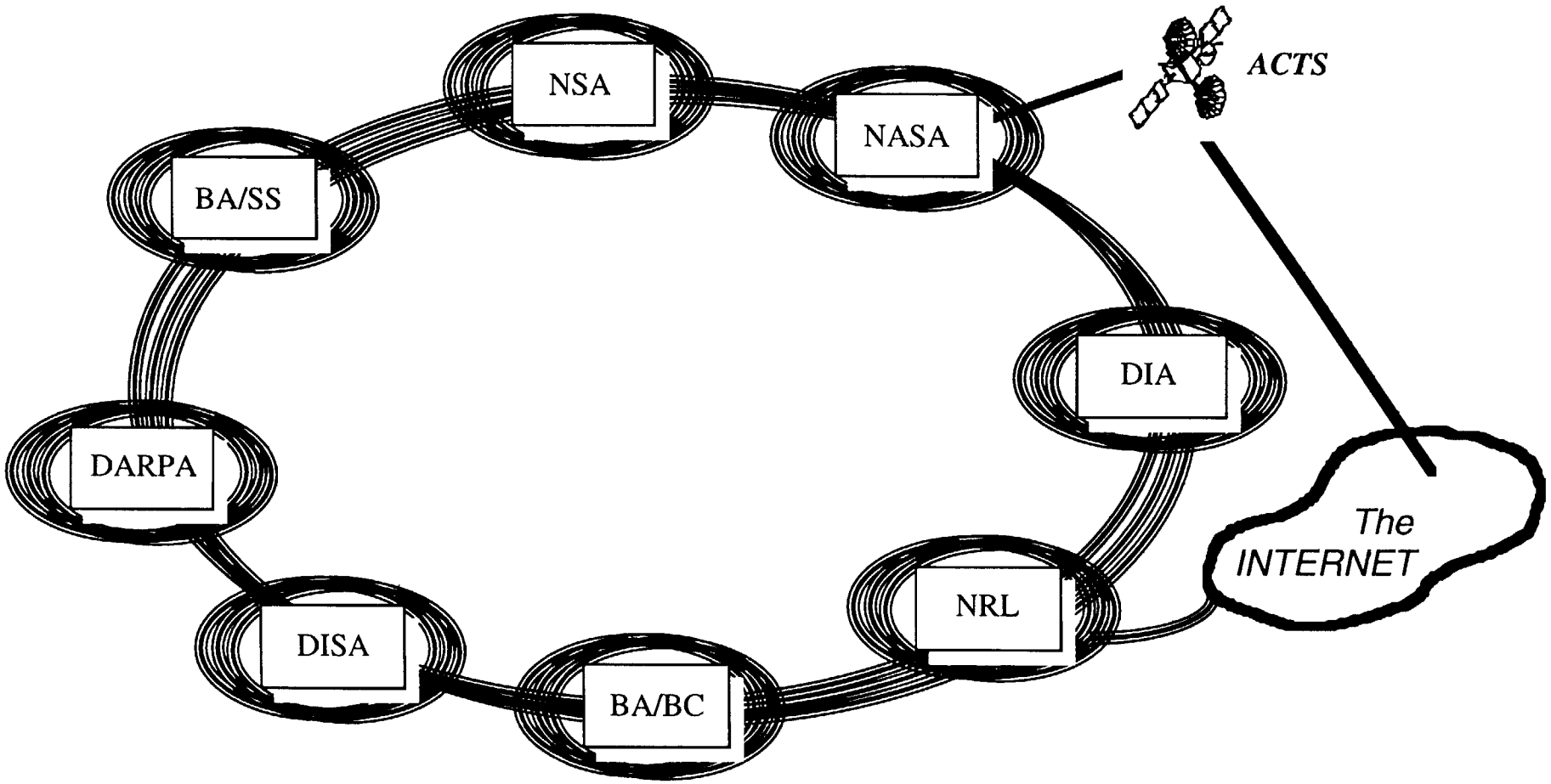
## ***Data Communications Protocols To Be Used/Tested***

- ATM data link layer
- IPv4, and possibly IPv6 network layer
- TCP with extended windows (LFN, RFC 1323) and selective acknowledgement (SACK, RFC 2018) options as a baseline for the reliable transport layer
- XTP with LFN and SACK as an experimental high performance reliable transport layer
- UDP for transport of MBone-based videoconferencing
- HTTP 1.1 for improved WWW-based data access

# ATDNet with Multiwavelength Optical Network (MONET)- the system of the future

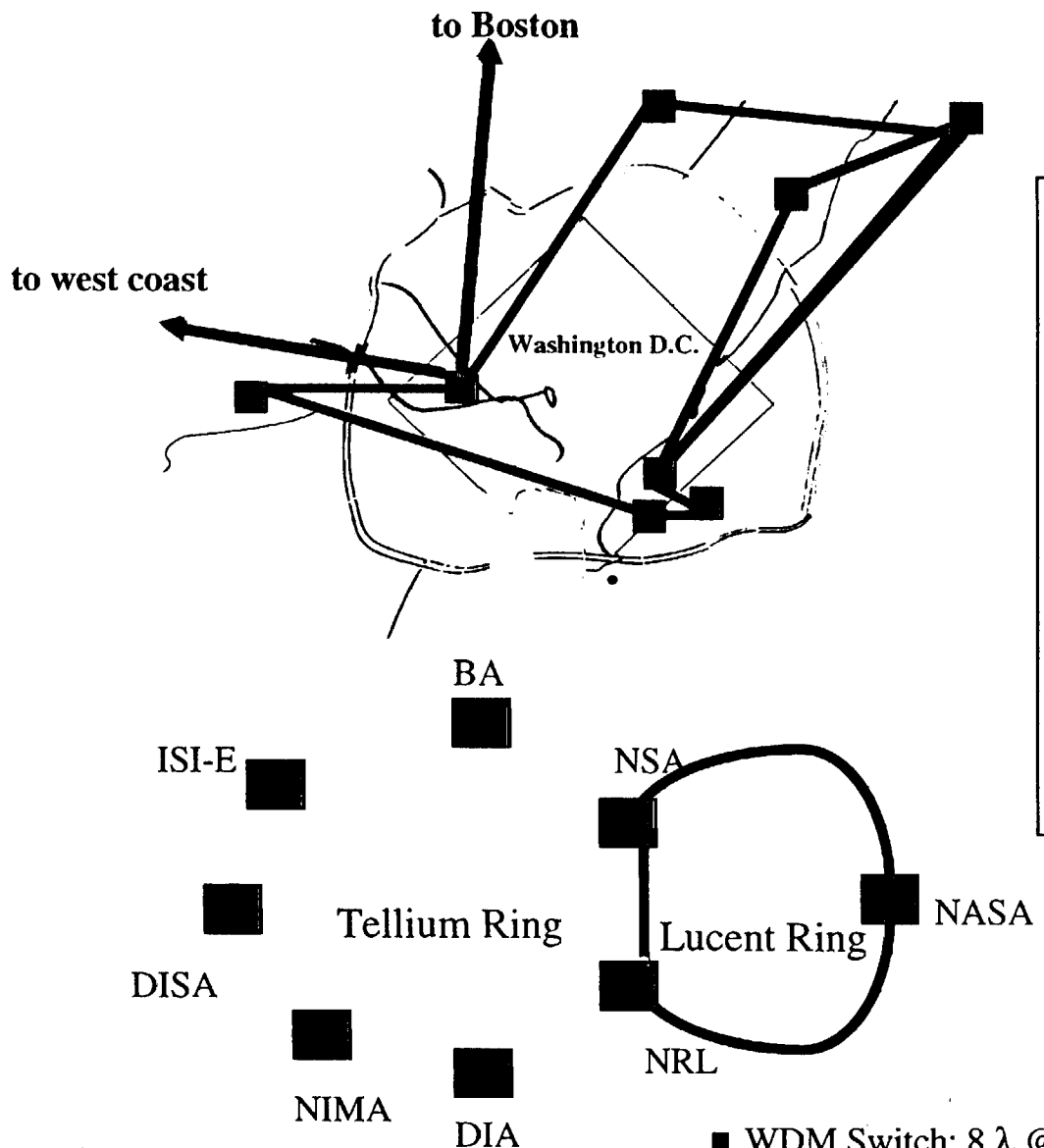
***Department of Defense:***

***ATDnet++*** *. . . A fully switched Wavelength Division Networking Testbed*




*Proposed late 1999-2000 : Mixture of wavelength interchange & wavelength select devices*

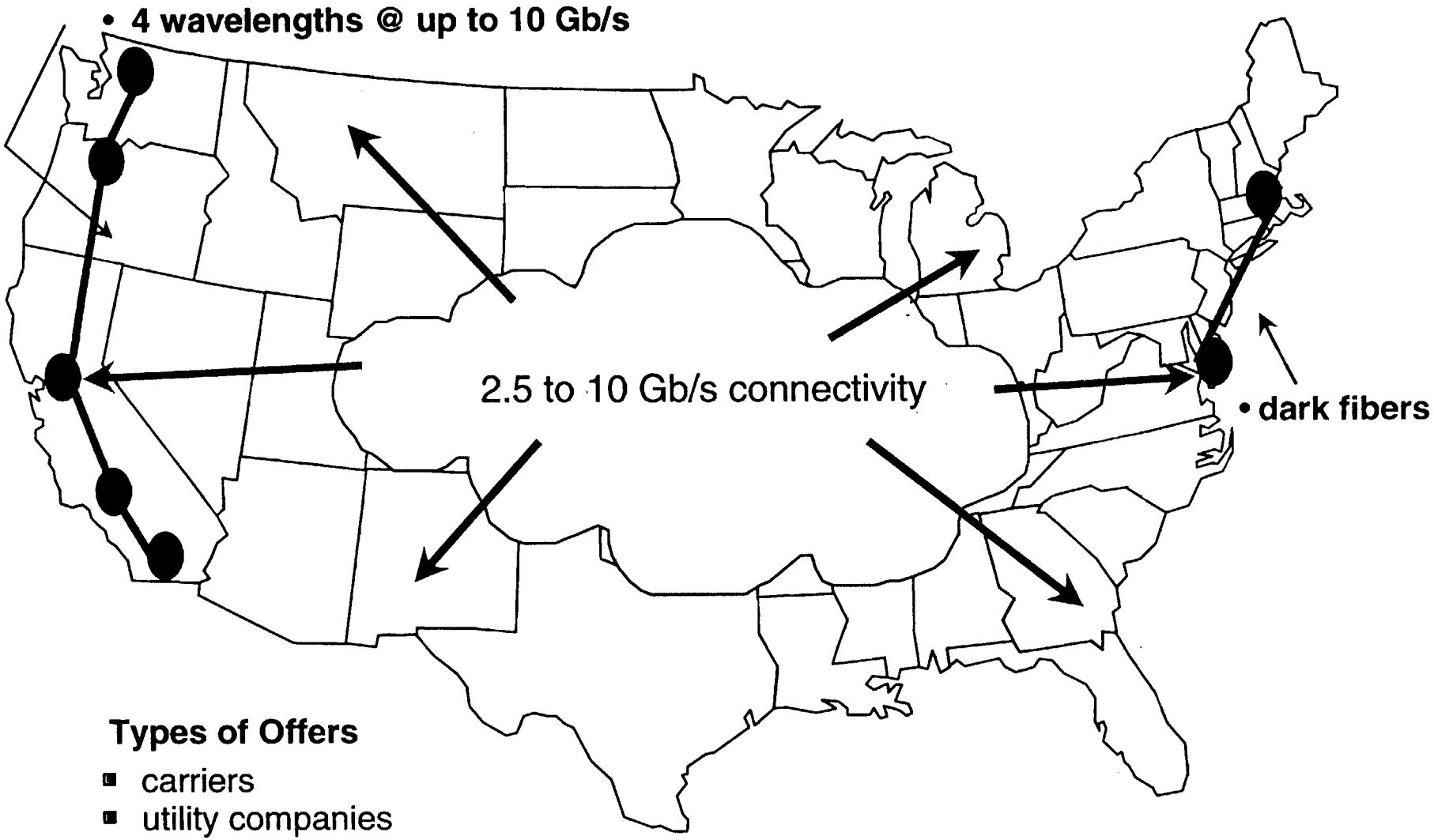
# ATDNet / MONET TESTBED




- Limits of Optical Transparency
- All-Optical "Just-in-Time" Switching
- Optical Self-Healing Rings
- Network Management & Control
- Multi-Vendor Interoperability

- WDM Switch: 8 λ @2.5 Gb/s per λ, to be installed in 2/99

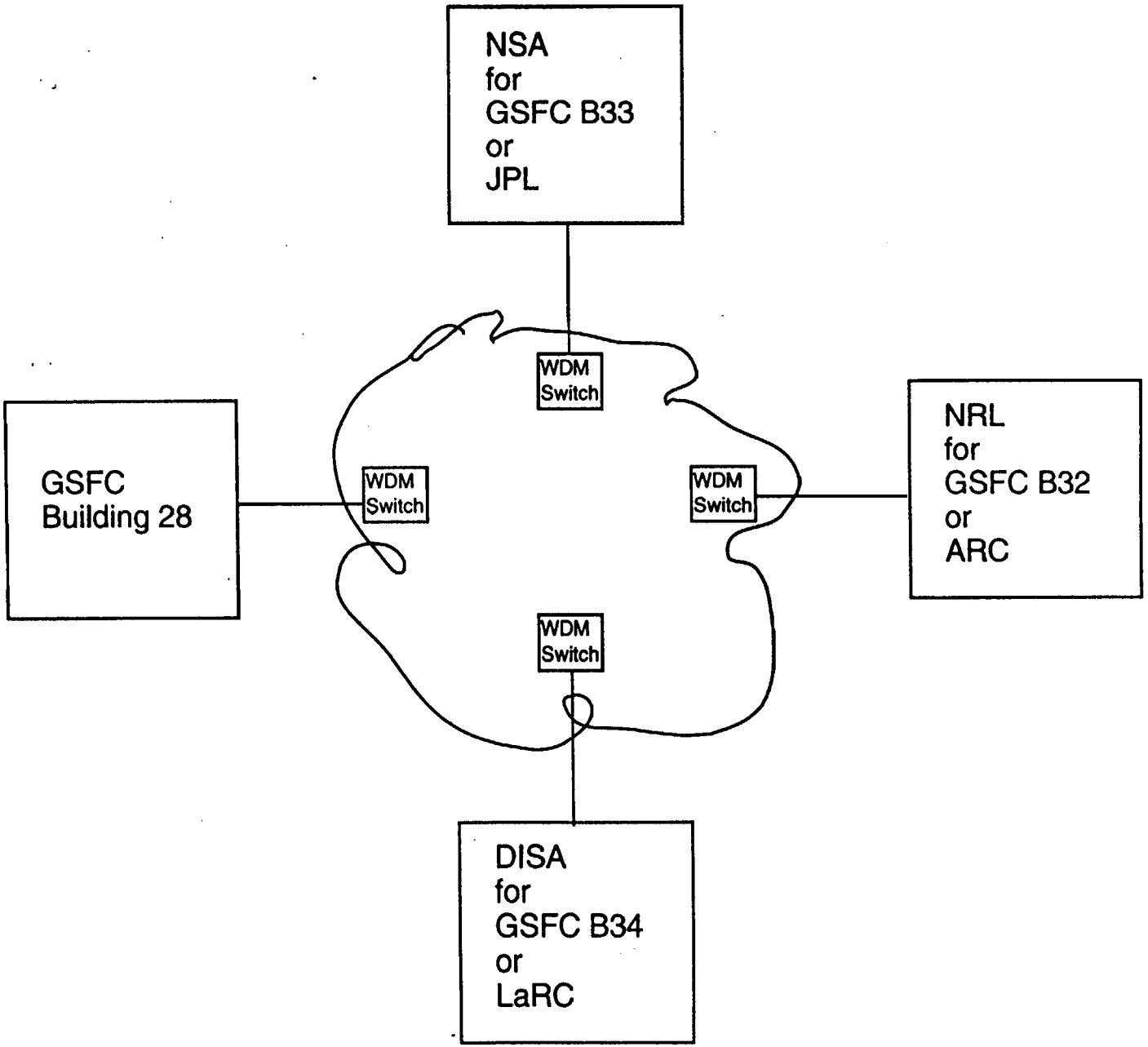
# DARPA SUPERNET TESTBED




**Types of Offers**

- carriers
- utility companies
- Internet service providers

# ATDNet/MONET Testbed of NASA WDM Requirement

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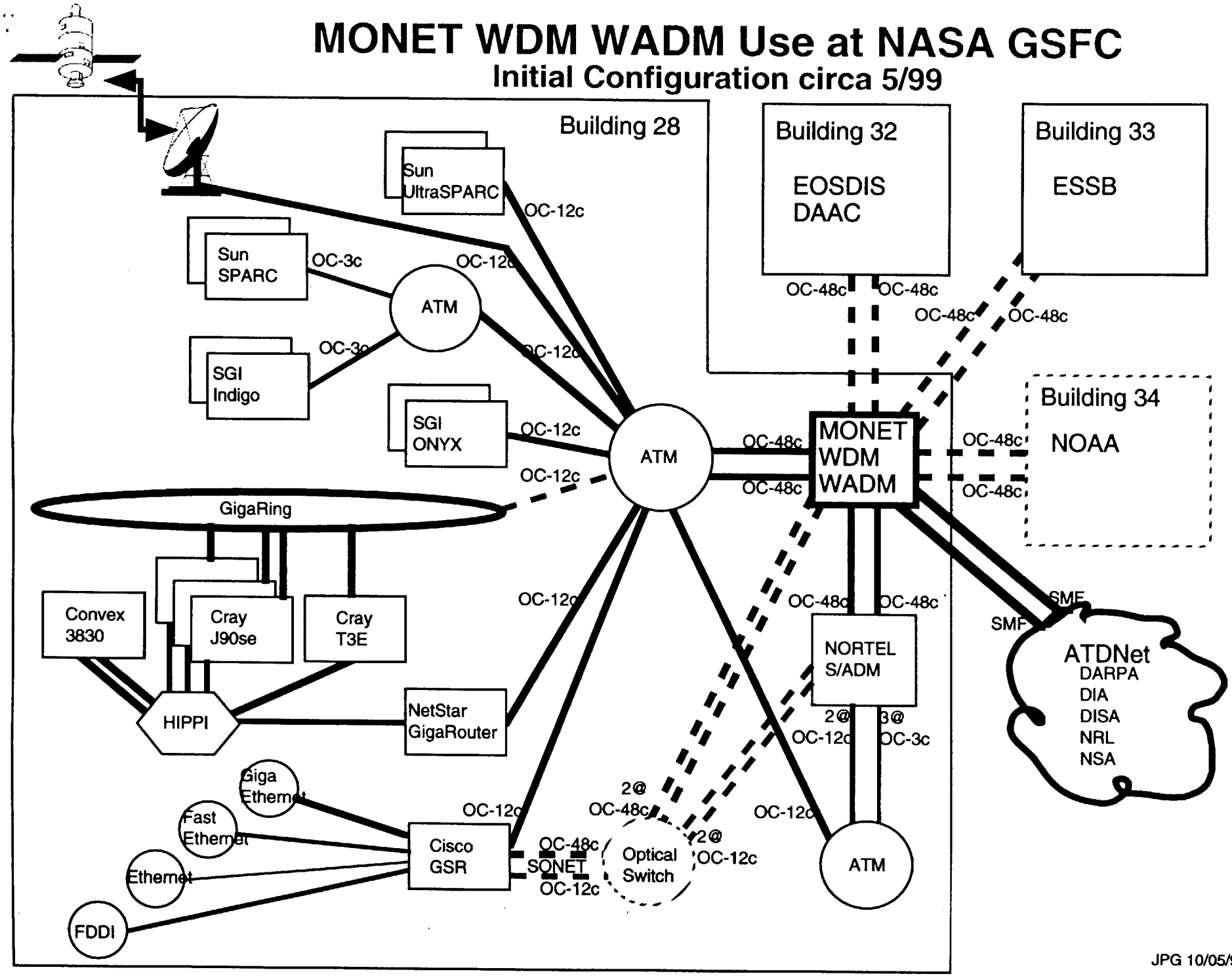
# MONET WDM WADM Use at NASA GSFC

## Initial Configuration circa 5/99

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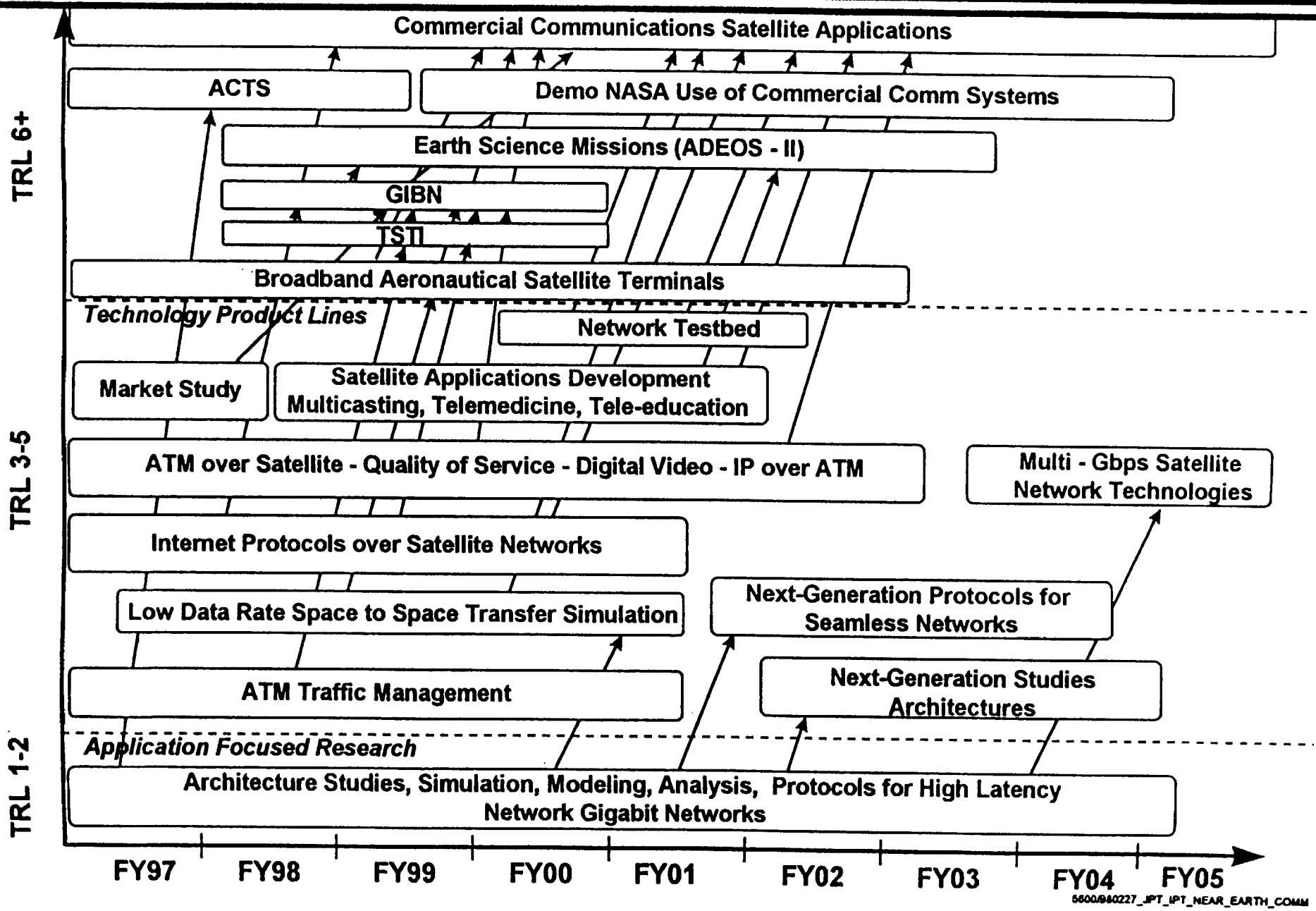
# Satellite Networks and Architectures



# ESDCD On-Going Network Projects
# More Info

- AAMNet: ADTNet-ACTS-MAGIC Network (622 Mbps)
  - http://everest.gsfc.nasa.gov/SCTB/AAMNET_plan.html
- ATDNet: Advanced Technology Demonstration Network
  - http://www.atd.net/
- GIBN DLE: Global Information Broadband Network Dig. Lib. Exp.
  - http://dlt.gsfc.nasa.gov/gibn/
- GLIN: Global Legal Information System
  - http://lcweb2.loc.gov/law/GLINv1/GLIN.html
- HECN: High End Computer Networking (for HPCC/ESS)
  - http://everest.gsfc.nasa.gov/
- TSTI: Testbed for Satellite and Terrestrial Interoperability
  - http://everest.gsfc.nasa.gov/TSTI/TSTI.html